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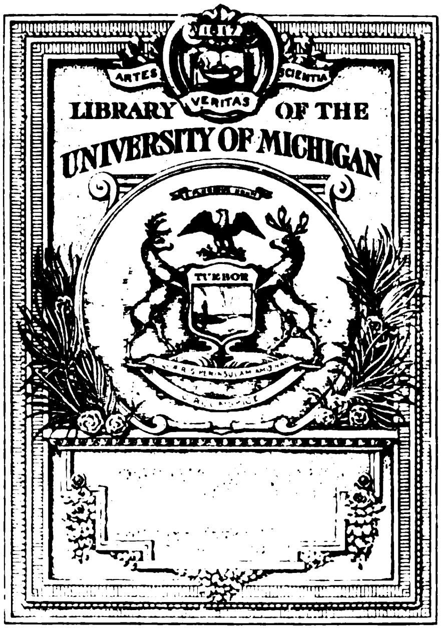

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REPORT

OF THE

SEWERAGE COMMISSION

OF THE

CITY OF BALTIMORE

CONSISTING OF

MENDES COHEN
F. H. HAMBLETON
E. L. BARTLETT

APPOINTED BY

JOINT RESOLUTION OF THE CITY COUNCIL

APPROVED 25TH MAY, 1893.

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REPORT OF CONSULTING ENGINEERS.

NEW YORK AND PROVIDENCE, *November, 1896.*

MENDES COHEN, Esq.,
F. H. HAMBLETON, Esq.,
E. L. BARTLETT, Esq.,
Sewerage Commission of the City of Baltimore.

Gentlemen:—In accordance with your letter of April 16, 1895, containing an outline of the services we are expected to render to your Commission, in recommending a plan for the collection and disposal of the sewage of your city, together with its estimated cost, and a thorough discussion of the subject, the present report is herewith respectfully presented.

A

INTRODUCTORY REMARKS.

At a joint meeting with yourselves, it was decided that we were to be at liberty to consult with each other regarding your work, but that we should give to you our individual opinions concerning our recommendations.

Since starting upon our labors, such consultations have been frequent and a number of visits to Baltimore have been made, jointly and separately. To aid us in doing our work, you have furnished each of us copies of necessary maps, reports, and the results of surveys and borings, made at our request; and in numerous conversations on the subject you have given us much information on local questions.

Personal examinations of all the important parts of the territory have been made, either alone or with yourselves, or with Mr. Kenneth Allen, your assistant.

The lines of the possible main interceptors have been examined; also the territory lying between the Back River and the Patapsco River, with reference to clarifying the sewage and also with reference to discharging it into Chesapeake Bay off North Point; also the land lying north and east of Back River; also the land lying south of Curtis Bay, as far as Magothy River, with reference to treating the sewage by filtration.

We have understood it to be the desire of your Commission to have an exhaustive enquiry made regarding the whole subject, so far as the general features of the problem are concerned, with a view to establish a comprehensive system of sewerage and drainage which will answer, practically, for all time.

Such a system you desired to be fully indicated in general outline, with its main features, so that it could be well comprehended, and its approximate cost ascertained.

Any detailed features, dependent upon minor conditions, and allowing some variations to be made when adapted to local requirements, must be given with the understanding that they should be so adapted, when it is decided to construct the works.

The assumptions regarding the requirements of the work have been liberal, but have been approximate only, which we consider sufficient for the present purpose. Later, when the works are to be constructed, the assumptions will need adjusting, and the many details will need to be carefully worked out.

Enquiry has been made with reference to these requirements, as presented to us, and the results are set forth in what follows:

B

OBJECT TO BE OBTAINED.

The necessity of a well-devised system of modern sewerage for a city of such magnitude and importance as Baltimore, requires no comment from us. It may be well to state, however, that the success of a system of sewerage depends, in a great measure, upon the carefulness with which it is designed and built, and upon the faithfulness with which the works are managed when in operation.

One advantage of a modern system of sewerage consists in removing all foul liquids in a proper manner and preventing them from running across the sidewalks and along the street gutters, as at present is customary in your city. The street gutters should be kept for the removal of rain-water only. Another advantage is, that all privies can be abolished and water-closets substituted. It is important that cesspools, as soon as superseded by sewers, should be thoroughly cleaned and thereafter immediately filled with clean material.

The city is continually extending its built-up area, the population is increasing, and the demands for proper sewerage are becoming greater. When considering this question, it is therefore necessary to look into the future far enough to ensure that the system when complete will be not only sufficient for the demands of the population of the day, but will have such surplus capacity as to answer practically for all time, so far as it concerns the territory which the system is intended to cover.

It may be stated, that works of such importance as these, for the execution of which necessarily skill of a high order will be required, and which are to be built, practically as a whole, may be designed with a smaller allowance for contingencies, such as possible improper arrangements of details and improper workmanship, than if the work were to be done unsystematically, in small patches, at different times and by different officers. The economy, also, of building so large a work within a short time, and under the same management, will likewise be apparent.

It is evident that the character of the works recommended for sewerage and drainage depends first, upon the topographical and geological conditions of the territory; secondly, upon the sewers and drains already existing, and thirdly, upon the methods available for disposing of the sewage. To these matters, therefore, attention is now directed.

C

GENERAL TOPOGRAPHY AND GEOLOGY.

The City of Baltimore lies near the head of the Patapsco River, which, about ten miles below the city, discharges into the Chesapeake Bay. The River has two branches, the Northwest and Middle Branch, which extend several miles into the territory of the city, the main river passing westerly outside of the city. The main harbor, called the Basin, is situated at the head of the Northwest Branch. It is comparatively narrow and extends almost to the heart of the business districts.

The topography of the city itself is flat near the water, and rises somewhat rapidly towards the north and west, so that the natural drainage of the city is good. The highest points within the city limits are situated in the northwest corner, where some territory rises above four hundred feet. The northeastern part of the city is not as high and the ground rises only to about three hundred feet above tidewater. In the southwest corner of the city it also rises to about three hundred feet. The total area of the city, including the water areas, is 32.21 square miles; excluding them, it is 29.54 square miles.

Several watercourses run through it. Jones' Falls, which is quite a stream, passes through the city near its centre, and discharges into the Northwest Branch. Gwynn's Falls, likewise a large watercourse, passes through the western part of the city, and discharges into the Middle Branch. Smaller streams, such as Gwynn's Run in the west, and Harford Run, Jenkins' Run and Stony Run in the north and east, and still others, break up the territory into numerous natural drainage areas, which eventually discharge into the two branches of the Patapsco River.

In the northeastern corner of your city, there remains a territory which does not drain into this river, but into Herring Run, and thence into the Back River. This territory therefore must receive a special consideration regarding its sewerage and drainage.

The excellent topographical survey of your city, prepared under the direction of Col. H. T. Douglas, and the model made in your office, very clearly show the physical characteristics of the territory.

In the suburbs there are numerous park areas which will remain uninhabited, and for which, practically, no provision need be made for sewage removal. These park areas, also, absorb a much larger proportion of the rainfall than do the built-up parts of the city.

The built-up territory is extending towards the higher ground in all directions, but mainly towards the north, and it is in this direction where also the greatest allowance must be made for future increase in the quantity of sewage and also for the run-off from heavy storms.

With reference to the subject of final sewage disposal, there is the large mass of water of the lower Patapsco River and Chesapeake Bay, into which the foul water might be discharged and diluted, and also the territory lying on each side of the river below the city, as Patapsco Neck, Marley Neck, etc., upon which it was thought the sewage might be purified.

A trip was made down the river into the Bay, and into Back River, in order to examine the surface conditions at the shores and the general currents of the water.

Patapsco Neck was carefully examined with reference to a possible treatment of sewage upon land, and also with reference to carrying an outfall sewer from the city near North Point. The special surveys and topographical maps made by Mr. Allen, show the character of this territory. Borings made in the lower portions of Patapsco Neck have indicated to us the character of its soil.

We also examined some of the territory on Back River Neck, in order to discover whether it was available for sewage treatment.

On the southwestern shore of Patapsco River, the territory was examined as far south as Magothy River, likewise with reference to the question of sewage disposal. A large number of borings five feet deep were made by Mr. Allen, showing the nature of that portion of the territory examined, which lies nearest the city. It was considered unnecessary, at present, to make closer examinations at more distant points, because the actual nature of the ground was generally apparent on the surface.

Hydrographic observations in the River and Bay were not made, because it appeared to be unnecessary to go to the expense of such observations in order to discuss the question of dilution.

The geological character of the ground, on which the city and its suburbs are located, has a bearing upon the construction of the sewers in the city, many of which will be deep; upon the disposal of sewage on land; upon the absorption of rain-water and its slow discharge into the streams by percolation; and also upon the present use of cesspools, into which foul liquids are discharged.

The character of the ground near the surface is generally clay, sand and gravel. Hence, excavations for sewerage purposes will not be unusually expensive. In the northern and western part of the city, and particularly in those sections which have not yet been built up, there will be some rock excavation. Rock crops out at the bottom of Jones' Falls above Eager street and also in the valleys of Gwynn's Run and Gwynn's Falls.

The territory of Patapsco Neck is largely covered with timber, and the soil consists mostly of loam, with occasional pockets of gravel and sand. In the southern portion of the Neck there is more sand than in the northern portion, but it is largely mixed with clay, and, therefore, its porosity is much decreased.

The soil near the surface of Back River Neck is quite similar, so far as an examination of the surface could determine. No extensive areas of sand or gravel are found in the higher territory northwest of these two necks. The soil immediately southwest of the city is likewise mostly clay and loam, as far as Curtis Bay. At this latitude, however, the clay strata begin to be covered with sand which is more or less free from the admixture of clay.

Going in a southerly direction, the sand layers increase in thickness and in freedom from such admixture at least as far as Tick Neck, where there are large areas of almost pure sand at the surface.

The ground on both sides of Furnace Creek and its branches, while showing more or less sand a short distance below the surface, is covered with a layer of soil, in which vegetation flourishes.

A close reconnaissance of these sandy areas was made by Mr. Allen, and a map showing the topography has been prepared by him.

We are indebted to the kindness of Prof. Wm. Bullock Clark, State Geologist, for a brief report on the geology of the site of Baltimore, and of the region adjacent to the Lower Patapsco River, and present the same in the Appendix to this report.

D

POPULATION.

In designing a system of sewers, it is necessary to provide for it a capacity sufficient to answer not only the present, but also the future requirements of the population. In most cities there are certain parts which have already received their probable ultimate development, so far as density of population is concerned.

Cities usually grow more by adding to their territory than by increasing the population within the already built-up sections. The proposed system of sewers should therefore be capable of extension into all directions which will eventually be built up.

POPULATION OF BALTIMORE BY WARDS.

Ward.	Area in acres.	Population in 1896.		Estimated Population.	
		Total.	Per acre.	Total.	Per acre.
1	595.2	29,150	49	31,000	52
2	249.6	18,520	74	19,000	76
3	153.6	19,310	126	21,000	137
4	153.6	17,750	116	20,500	133
5	140.8	18,740	133	20,500	146

Ward.	Area in acres.	Population in 1896.		Estimated Population.	
		Total.	Per acre.	Total.	Per acre.
6	1,024.0	37,500	37	81,000	79
7	326.4	37,300	114	38,000	116
8	480.0	30,300	63	31,000	65
9	332.8	19,060	57	30,000	90
10	136.0	19,550	144	20,500	151
11	204.8	24,550	120	25,500	124
12	441.6	29,930	68	36,500	83
13	172.8	18,190	105	22,500	130
14	166.4	21,870	131	22,500	135
15	172.8	17,800	103	21,000	122
16	134.4	17,820	133	18,500	138
17	1,222.4	34,190	28	91,500	75
18	1,120.0	35,920	32	70,500	63
19	480.0	34,140	71	38,500	80
20	307.2	28,360	92	31,000	101
21	6,982.4	28,770	4	108,500	16
22	3,904.0	36,230	9	152,500	39
East of city limits,				48,500	
		574,950		1,000,000	

In order to obtain an estimate of the present density of population, and in order to make an estimate of the future density, the above table has been prepared.

The present population, the areas in acres, also the density, are given for each ward. The two last columns give the estimated population and its relative density when there are one million inhabitants. Such a population, in consultation with yourselves, it was thought proper to allow for when proportioning the capacity of the sewerage system.

It may be added that an increase of population beyond the assumed figure will not require an enlargement of the sewers, now recommended to you. The greater population will occupy additional territory and therefore require more sewers; perhaps, also, an additional intercepting sewer. This requirement has been given due consideration, and it will be practicable, in the future, to build other sewers, in order to relieve any surcharge of those already existing, and at the same time, form a proper part of the entire system. In other words, it will not be necessary to rebuild or cause to be useless any essential and material part of the work now proposed.

To indicate the assumed distribution of the population, and thereby to make it convenient to ascertain the population on every area contributing to a given sewer, a population map was constructed by placing a red dot at what was assumed to be the centre of each five hundred of the prospective population. By counting the dots in each sewerage district, we determined the quantity of sewage to be expected therefrom.

It will be noticed that in the built-up parts of the city there is no very large difference in the density of population. We have assumed that this characteristic will generally be retained, although it is true that in the business centres of our large American cities the "day population" is increasing to very large numbers. We think that a suitable allowance in the capacity of the lateral sewers will provide for this fact.

E

WATER SUPPLY, SEWAGE AND GROUND-WATER.

The present population of the city is about 575,000. The greatest consumption of water recorded by the City Water Department is about 72,000,000 gallons per day. As the city water works supplies a small population in the Highlandtown and Canton District east of the city limits, the present consumption of water averages only about 120 gallons per head of the total population in the districts where city water pipes are laid. At this average rate the total consumption of water of one million inhabitants would be about 120,000,000 gallons per day.

The proposed low level system of sewers of the filtration project will collect sewage from an area that is practically identical with that covered by the proposed Low Service and Middle Service Districts, recommended in the Report to the Water Commissioners and recently adopted. From the data given in that report it is estimated that the maximum consumption of water in these two Districts will be about 74,650,000 gallons per day for a population of about 560,000, at the time when the city will have one million inhabitants. This gives an average consumption of about 133 gallons per head.

The proposed high level system of sewers for the filtration project will collect the sewage from all the remainder of the city's area, which is practically identical with the area covered by the proposed High Service and Upper Service Districts, as rearranged in the report above mentioned. From the data given therein it is estimated that the maximum consumption of water in these two Districts will be about 46,000,000 gallons per day for a population of about 440,000 when the city has one million inhabitants. This gives an average consumption of about 105 gallons per head per day.

The low level system of the dilution project collects sewage from an area that is practically identical with the proposed Low Service District, and the high level system from an area which is practically identical with the proposed Middle, High and Upper Service Districts. Again, from the data given in the above mentioned report, there is an average daily consumption in the former of about 140 gallons per head and in the latter of about 112 gallons per head per day.

The proposed increase of pressure of water throughout the system will surely tend to increase the consumption, and in the absence of restrictive measures against wastefulness it cannot be expected to be kept within reasonable bounds.

Irrespective of the expense of furnishing an excessive amount of water to your population, it will be desirable in the future to adopt effective measures for the prevention of waste, because the water will have to be dealt with a second time, namely, as sewage. A larger consumption than necessary will not only increase the size required for all of the sewers and force mains, but the sewage will have to be pumped to a considerable height, and all of it subjected to a process of purification.

We have made a provision for 150 gallons per head of population per day to reach the intercepting and outfall sewers as sewage, and we are of the opinion that this amount is both reasonable and sufficient. An increase beyond the same would be due to waste, which should be and can be prevented. Or, it would be due to the use of water, perhaps for power and other similar purposes, which would not cause it to be fouled. Therefore it does not require to be discharged into sewers and delivered at the purification works, but can and should be discharged into the drains provided for the removal of rain-water.

The use of water is not uniform throughout the twenty-four hours of the day. We find its greatest use to be during the forenoon and its least use to be during the small hours of the night.

For District main and branch sewers the maximum flow may rise to double the average, on account of the hilly territory and rapid collection. For the intercepting and outfall sewers we have allowed a maximum flow equal to fifty per cent. greater than the average.

Sewage consists of the waste or refuse water from buildings after it has served the general purposes of cleansing, and been fouled by the discharges from bath-rooms, water-closets, urinals, kitchens, laundries, sculleries, stables, factories, etc.

Rain-water flowing off from streets with heavy traffic is sometimes as foul as domestic sewage. But as efficient street cleaning will prevent an objectionable result, we do not consider it necessary to treat it as being equally foul, nor as becoming objectionable when entering the drains, the rivers and the harbor.

When a water supply is liberal, the appearance of sewage is like dirty water. It consists of about 998 parts of water, about one part of organic matter, and perhaps one part of mineral matter. The organic matter contained in the sewage is that which by putrefaction causes the subsequent nuisance.

At first it has a very slight odor, resembling that of laundry water, on such days when much washing is done, and on other days it generally has the odor of an uncleaned kitchen sink.

In a new system of sewers, properly built and well cleaned, we have repeatedly detected these odors, as described, at the outfall. After sewers have been used for some time, and particularly where they are not carefully cleaned, a foul odor is detected, and it increases in proportion to the neglect in the care of the system. Where old sewers, that have been long in use and are improperly constructed, or where overflowing cesspools are connected with a new system, the odor at once becomes foul, because they contain much putrefying matter which readily affects the condition of the passing fresh sewage.

Although an effort should be made to prevent ground water or sub-soil water from entering the sewers, we have made an allowance for the infiltration of 100,000 gallons per day per square mile of territory. The ground water of the low districts of the city should be disposed of by other channels, as indicated below.

With the maximum flow of sewage and ground water, as thus estimated, we have assumed that the intercepting sewers should run half full, and the outfall sewer on Patapsco Neck two-thirds full. The force mains delivering the sewage at the filtration fields must of course run full at all times.

While we believe that 100,000 gallons of ground water per square mile per day is sufficient allowance throughout the greater part of the city, we do not think it is sufficient in the low parts of the city near the harbor. The reason for assuming a larger quantity in this locality is the fact that much of the ground water in the higher parts of the city will descend below the levels of the sewers and drains and reappear at the level of the intercepting sewers in the lower parts of the city. We have estimated that means should be provided at these sewers for removing ground water to the extent of 1,200 gallons per day per acre, or about 750,000 gallons per square mile.

F

RUN-OFF FROM STORMS.

In designing drainage works it is of greatest importance to ascertain the quantity of water per unit of surface, for the removal of which provision should be made.

Underestimating this quantity and thereby making the sewers, drains or other channels too small, would result in flooding streets and cellars, and damage to property. It must therefore be avoided. On the other hand, too great an allowance should not be made, as the sizes of the drains and other structures, and consequently their cost, would be unnecessarily increased. The problem requires that a proper medium be maintained between the two extremes.

The amount of rain-water for which provision should usually be made has not yet been satisfactorily determined, because it varies with a number of conditions, some of which can be expressed by a formula, while others must depend upon judgment, and because as yet an insufficient number of observations have been made on the subject to know the precise relationship of the factors.

We may say that the run-off varies with the amount of rainfall, and also with the slope, imperviousness, dryness, shape and extent of the area.

Observations are being made on the run-off in the City of Washington by the Engineer Commissioners of the District, and information, valuable also for Baltimore, will no doubt be there obtained in time. It will be sufficient for the present purpose to analyze some of the usual formulae that have been proposed, and, as they are fairly applicable to Baltimore, to apply them intelligently until better results are available.

The formulae discussed below are those of Hawksley, Adams, Burkli-Ziegler, McMath, and one deduced from diagrams prepared for the Department of Public Works of New York, in 1889.

They are as follows:

Let Q **= Run-off in cubic feet per second.**
r **= Maximum rate of rainfall in inches per hour.**
c **= A coefficient dependent mainly on the character of the surface.**
A **= Drainage area in acres.**
S **= Average slope of area per 1,000 feet measured along the flow lines.**

Then, according to:

Hawksley, $Q = c\sqrt[4]{r^3A^3S}$
for $r = 1$; $cr = 0.70$

Adams, $Q = c\sqrt{r} \,.\, \sqrt[6]{A^5} \,.\, \sqrt[12]{S}$
for $r = 1$; $cr = 0.57$

Burkli-Ziegler, $Q = cr\sqrt[4]{A^3S}$
for $r = 2.75$; $c_1r = 2.0625$ for paved and built-up areas.
$c_2r = 1.705$ for average city areas.
$c_3r = 0.8525$ for rural areas.

McMath (for St. Louis), $Q = cr\sqrt[6]{A^4\ S}$
for $r = 2.75$; $cr = 2.0625$.

New York Diagrams, $Q = crA^{.85}S^{.27}$
$c_1r = 1.64$ for completely built-up areas.
$c_2r = 1.39$ for well built-up areas.
$c_3r = 1.02$ for suburban areas.

(a) *Maximum Rate of Rainfall.*

The most important factor is, of course, the greatest rate of rainfall. It is necessary to have exact observations not only concerning large storms, but also concerning those which have the greatest intensity.

The records of a number of excessive storms, which have occurred

during the past twenty-five years or more at several places in the State of Maryland, and also in the cities of Washington and Philadelphia, have been extracted from "The Weather Review" published by the Department of Agriculture (formerly by the Signal Service of the War Department), and are given in the Appendix.

Among these storms there are a number which were recorded by automatic gaugings and which for that reason are more useful in the present instance than the others. Such records have been plotted on the diagram contained on Plate N, the lesser storms being omitted as unnecessary. The ordinates represent the rate of rainfall in inches per hour, and the abscissas the duration of this rate in hours and minutes. The locations and dates of those storms which have exceptionally great rates and durations, are indicated outside of a dotted curve. The greatest storms have been designated specially, regarding place and date of occurrence.

From a study of these records it appears that the drains should be proportioned for a run-off from storms having a rate of 4 inches per hour.

In New York City a rainfall of one inch in 10 minutes or at the rate of six inches per hour, has occasionally been recorded, and this rate may be used for proportioning the drains from private premises and from short blocks.

The formulae above mentioned assume the run-off to vary with the rainfall, as follows:

All factors, excepting the run-off and rainfall, are assumed in this comparison to be constant.

$$\begin{array}{ll}
\text{Hawksley,} & Q = \text{constant}\,.r^{.75} \\
\text{Adams,} & Q = \text{constant}\,.r^{.50}
\end{array}$$

$$\left.\begin{array}{ll}
\text{Burkli-Ziegler,} & Q = \text{constant}\,.r \\
\text{McMath,} & Q = \text{constant}\,.r \\
\text{New York Diagrams,} & Q = \text{constant}\,.r
\end{array}\right\} Q \text{ varies directly with } r.$$

There is hardly a question that, all other factors being equal, the run-off from such small areas as are considered for city drainage, should vary directly with the rainfall in all cases of heavy storms, and also for short periods if absorption and evaporation can be neglected. Therefore, as these assumptions can generally be made for city work, the three latter formulae which have a direct variation with the rainfall are preferred.

(b) *Slope.*

When the maximum rate of fall does not cease before the run-off from the entire area has reached its lowest point, then for this area the run-off will be independent of the slope. But when the maximum rate ceases before this takes place, the slope will have a decided influence upon the quantity of water accumulated.

The greater the slope of the surface, that is, the steeper the territory, the more rapidly will the water run off and accumulate along the lowest lines.

It is not practicable at this time to state how large the area must be before the variation of the slope should be considered. It depends upon the maximum rate of rainfall, upon the steepness of the area and upon other local conditions. For the present purpose the question will be neglected, as the information regarding it is still too indefinite.

Assuming, generally speaking, that the run-off increases with the slope, what is the ratio between these two quantities?

If all factors excepting the run-off and slope are assumed to be constant, then the above mentioned formulae exhibit the run-off to vary with the slope in the following ratios:

Hawksley,	$Q = \text{constant } S^{.25}$
Adams,	$Q = \text{constant } S^{.083}$
Burkli-Ziegler,	$Q = \text{constant } S^{.25}$
McMath,	$Q = \text{constant } S^{.20}$
New York Diagrams,	$Q = \text{constant } S^{.27}$

The exponent to the value S, exhibiting the ratio, does not show any great difference, excepting in the formula of Adams. The latter has the smallest exponent and the New York Diagram the largest; the latter, therefore, indicates a greater variation due to the slope that the other formulae.

(c) *Imperviousness and Dryness.*

These two characteristics of the surface are represented in the above formulae by a coefficient c, which must vary with the degree of imperviousness and dryness of the surface. Open ground, such as fields, parks and gardens, is comparatively pervious, while roofs and pavements are impervious. A wet soil will be less pervious to a sudden heavy rainfall than a dry one. Dry and hot street and roof surfaces will cause more evaporation than wet and cool ones. But this variation is of no practical importance in the present case, as, by the time the maximum rate of rainfall occurs, all surfaces are thoroughly wet and cool.

It is assumed in the above formulae that c varies directly with the degree of imperviousness, that it is constant for each degree, and that therefore the run-off Q varies directly with c.

(d) *Shape of Area.*

None of the formulae mentioned take any account of the shape of the area, although it must necessarily affect the quantity of run-off. A violent and short rainfall upon a long and narrow area produces a smaller run-off at a given point, other things being equal, than upon a short and broad area. Still, for city drainage areas, which are comparatively small, this variation is not of material consequence, and has therefore not been considered. Owing to the lack of data, it is hardly worth while to consider it at all in your case.

(e) *Extent of Area.*

The larger the area, the greater is the total run-off. But, the larger the area, the smaller is the run-off per unit of area, as for instance per acre. This variation is important and demonstrates that a drain taking the water from a large area, say 100 acres, does not require to have ten times the capacity of one taking the water from only 10 acres.

Assuming all the factors, excepting the run-off and drainage area, as being constant, then the above formulae give the following values:

Hawksley,	$Q = \text{constant}\ A^{.75}$
Adams,	$Q = \text{constant}\ A^{.833}$
Burkli-Ziegler,	$Q = \text{constant}\ A^{.75}$
McMath,	$Q = \text{constant}\ A^{.80}$
New York Diagrams,	$Q = \text{constant}\ A^{.85}$

As regards the effect of the extent of the area upon the run-off, it will be seen that the coefficient does not indicate any great difference between these formulae.

(f) *Conclusion.*

All the above formulae have the form

$$Q = cr^{o}A^{m}S^{n}$$

From what was said above, the only formulae giving an exponential value for r other than unity are those of Hawksley and Adams, and it is as well to ignore such variation. Therefore the preferred formulae have the form

$$Q = crA^{m}S^{n}$$

As they are practically derived independently of a knowledge of the exact maximum rainfall, we may substitute for cr the value of C, and therefore write

$$Q = CA^{m}S^{n}$$

In the Burkli-Ziegler formula we may therefore assume for the greatest storms the values:

$C_1 = 2.06$, for built-up areas.
$C_2 = 1.71$, for average areas.
$C_3 = 0.85$, for rural areas.

McMath's formula for the City of St. Louis, gives the value

$$C = 2.06$$

On the New York Diagrams the values are:

$C_1 = 1.64$, for completely built-up territory.
$C_2 = 1.39$, for well built-up territory.
$C_3 = 1.02$, for suburban territory.

Either of these formulae, if judiciously applied, will be useful in determining the proper sizes for drains in the City of Baltimore.

G

EXISTING SEWERS.

The City of Baltimore is, at present, without a system of modern sewers. The use of cesspools for the reception of excrementitious matter is almost general. The human dejecta are now retained in them until periodically removed by excavation. On the sloping territory some of these accumulations are naturally on ground which is higher than that upon which other dwellings are located, and in porous ground there will naturally be a percolation of the liquids to lower territory where they may reappear near the surface. That they will be somewhat purified is beyond a doubt, and it is also certain that the purification will in some cases not be complete, and occasionally cause conditions which may be dangerous to health.

Nevertheless, the death rate of the City of Baltimore is not high. But it is higher than its topographical location justifies, and higher than in many other cites, which though much less favorably situated, have a better system of sewage collection and removal.

Waste water from kitchens, bath-rooms, etc., is generally turned out on the surface of the ground and runs away in the open street gutters, thence into drains and finally into the watercourses at points where the discharge of such foul liquids must become objectionable.

In a few instances, private sewers are said to discharge into some of the drains now acting as public sewers, and into open watercourses or directly into the harbor. In many instances, it is said that the cesspools have overflows into the drains.

Here and there some better means of sewage collection and removal may be in use, but the instances are few, and have therefore no bearing upon the design of a system of sewers.

It should be stated here that a clear distinction is to be made between sewers and drains. The former are channels which receive and carry away foul water or sewage from houses, and are always closed in. The latter may be open or covered, and are channels which receive and carry off rain-water, sub-soil water, or, in general, any water that is not foul or not sewage.

In Baltimore it was intended that the large drains, locally called sewers, should carry off only surface and sub-soil water. But in the absence of a sewerage system the polluted gutter water or sewage enters the drains. It was expected that at some future day this condition would be changed.

The drains have, therefore, been built in a manner which may be justified, if they are to be used for the removal of comparatively clean water. They are not built in a manner which will make them serviceable for the removal of foul water or sewage.

A few of these drains lately built were personally examined by one of us. They were found to have been built of good material, and the workmanship appeared excellent. So far as could be judged the sections were well constructed for strength and durability.

A number of the newer and older drains were examined as to their capacity, and it was found that they are sufficiently large to carry off the rain-water from the heaviest storms that may be liable to reach them.

A few of the older drains, such as that on Central Avenue, are quite inconsistent as to sizes and should be remodeled.

In the Appendix a table gives the results of a few calculations concerning the present size and capacity of the drains, and also of the capacities which will be necessary in the future. Some will, no doubt, need remodeling, according to the principles mentioned under Section R.

The water, as it flows out of the present drains, resembles sewage, although it may not contain as much organic waste matter as will be found in a modern system of sewerage. As the drains are not constructed to remove sewage rapidly and completely, there is much decomposition and foulness, and the sewage at some points is therefore now even a more obnoxious liquid than is generally found at the outfalls of properly designed sewers. It is discharged at the heads of bays where there is but very little circulation of water. The slight tidal rise and fall at Baltimore does not remove it properly, and allows it to accumulate and increase in foulness.

H

MODERN METHODS OF SEWAGE DISPOSAL.

The object of a modern system of sewerage is to remove as quickly as possible from inhabited territory the sewage discharged from the buildings. The removal should not only be rapid, in order to prevent decomposition before the sewage is disposed of, but it should also be thorough and not allow of deposits or accumulations in the sewers, which create foulness within them and cause the escaping air to pollute the atmosphere. A further object of modern sewerage is to dispose of the offensive liquids finally in such a manner that they will cause no nuisance and that they are converted into uninjurious and inoffensive liquids.

There is no need of stating to you that the only proper method of sewerage for a large city is the water carriage system, by which the waste matters from buildings, such as can be suspended or dissolved in running water, are carried away by it. No reference will therefore be made to other methods, some of which still have their advocates. No reference will be made to the use of earth closets. Though excellent for individual houses to which a sewer is not accessible, and excellent for the disposal of excrementitious matter alone, yet they cannot be considered a part of a sewerage system for a city, because they do not dispose of the large quantity of fouled waste water.

There are several methods according to which sewage can be safely and properly disposed of, namely, by a dilution in large bodies of water, by precipitating and separating from the sewage a large proportion of the organic matter, and by filtration of the sewage through porous soil. These methods will now be discussed more fully, together with their application to the City of Baltimore.

It should be added at this place that the object to be obtained is first and foremost a sanitary one, namely, the purification of the sewage. The question of cost, though important, is but secondary.

It may also be added, that the question of utilizing the manurial elements contained in the sewage must be decided upon the basis of cost. If the expense of extracting these elements is greater than the price at which they can be sold, it is preferable to waste them. The latter conclusion is the usual one. When sewage is purified by filtration on land this land can usually be devoted to the raising of crops. But experience has shown that the increased productiveness is due quite as much to the liberal irrigation with water as to any fertilization derived from the same. It is often necessary to use additional fertilizers to produce the desired crops. But the ill effect of droughts is entirely avoided and the farmer is more sure of his crops.

I

DILUTION.

To dispose of sewage by dilution means to discharge it into running water in a suitable proportion so that no putrefaction will take place, and that the oxygen contained in the water will gradually decompose the organic matter of the sewage and convert it into harmless compounds. When sewage is thus diluted it gives no offense.

We have examples of this in the discharge of sewage into large streams, such as the Mississippi, Missouri, Ohio and Schuylkill rivers, which are all even used for drinking water. It must be understood, however, that the question in which we are here concerned does not refer to the discharge of sewage into a stream which is subsequently to be used for drinking purposes.

The question as to whether or not sewage may be properly discharged into a given river, is decided by the degree of nuisance that will be caused by the pollution. This nuisance is partly due to the unsightliness of sewage matter stranded along the shores or on any shoals that may exist during low water. It is mainly due to the offensive odors that arise from putrefaction. Putrefaction occurs when there is insufficient oxygen present in the water to allow the dead organic matter to be decomposed solely by oxidation, which is itself not an offensive process.

While it is therefore practicable to discharge some sewage into the running water of streams, there is a limit to the quantity when the excess of free oxygen contained in the water becomes insufficient to oxidize it. To obtain the best results by this dilution method of sewage disposal, it is necessary to have the sewage matter dissolved or well comminuted so that it can be thoroughly exposed to the action of the oxygen.

Therefore, no constant relation can exist between a certain quantity of sewage and the amount of flowing water that will render it innocuous. Where the velocity of the stream is lessened and there is consequently a chance for deposit, sewage will require a greater dilution than if the flow is rapid and continuous.

As a measure of the amount of permissible pollution, the sewage should be indicated, not so much by its actual quantity, as by the population from which it comes, and by the quantity of manufacturing refuse which it contains. The amount of waste organic matter is more constant with reference to a given number of persons than to the amount of the sewage coming from them. The latter depends almost entirely upon the liberality with which the public water supply is used and subsequently discharged as sewage.

It has been found that the sewage from one thousand persons can be satisfactorily diluted in non-tidal streams by a flow of water varying from two to seven cubic feet per second, according to the different conditions of the stream. Under the conditions found in Baltimore, where there is a very sluggish flow of upland water, and also a slight tidal current, it would not be safe to allow less than a minimum flow of three cubic feet per second to render the sewage of one thousand persons inoffensive.

When sewage is discharged into a tidal stream, it must be realized that the fluctuation of the tide causes not only a downward, but also an upward current. Therefore sewage discharged into it will oscillate and be carried away much more slowly than the apparent outflowing water of ebb-tide. The question of dilution in tidal streams is therefore almost entirely one of dilution by the upland water which enters the stream and gradually pushes out into the ocean.

The oscillation of a large quantity of tidal water has, besides, the effect of a more thorough dispersion by the greater velocity and mass of the water, also the effect, which is sometimes beneficial, of causing a deposit of the heavier matter, which will thus free the water from carrying it in suspension and more highly polluting it. The deposited matter is then sometimes carried away or dispersed during freshets.

If the tidal stream though wide, is also short, there is another beneficial effect in the circumstance that a large proportion of the sewage is carried out into the larger body of water where the tidal stream discharges, and with the incoming tide does not always return into the stream. It is therefore permanently removed from it.

In connection with this method of disposal it should not be forgotten that a discharge into salt water causes a less rapid oxidation than a discharge into fresh water; and also that the value of fish and other aquatic animals in disposing of sewage is very slight, and should not be counted on.

The effect of sewage discharged upon oyster beds, wherever sufficient inquiry was made, has been found deleterious. Evidence has been obtained, for instance, in New Haven, that the discharge of sewage near oyster beds, and the subsequent eating of the oysters, caused typhoid fever. Similar evidence has been obtained elsewhere.

In order to show the probable effect of discharging sewage into the Patapsco River at different points under the least favorable conditions, the necessary calculations were made. These conditions occur when the dry weather flow enters the river from its drainage area, and therefore contributes the least amount of water to dilute the sewage.

The best available information regarding the least dry weather flow of the streams about Baltimore is as follows:

From the United States Census of 1880 we find that the dry weather flow of the Patapsco River above Ellicott City and above Relay is about 0.22 cubic feet per square mile per second.

From information furnished by the Water Department of the City of Baltimore we find that the dry weather flow of Gwynn's Falls is 0.41 cubic feet per square mile per second, and that of Jones' Falls is 0.44 cubic feet per square mile per second.

From the United States Census we learn that the minimum flow of Rock Creek at Washington, D. C., is 0.114 cubic feet per square mile per second.

In our calculations we have assumed that the minimum flow from the creeks and from the general territory within the City of Baltimore, including the Patapsco River, is 0.2 cubic feet per square mile per second.

The entire drainage area of the river above a line drawn from North Point to Rock Point, is 556 square miles. The minimum flow of upland water at the mouth of this river would therefore be about 111 cubic feet per second.

If we assume that the sewage of 1,000 persons can be properly diluted in a large body of water by a minimum flow of 3 cubic feet per second, then the Patapsco River could, without becoming offensive, receive the sewage of about 37,000 persons.

It will be evident, therefore, that no system of sewerage that is recommended for your city should contemplate the discharge of all of its sewage into this river. It will be necessary to reserve its limited diluting power to counteract the effects due partly to the refuse discharged into the river and its branches from the ships and wharves, partly to the refuse which is brought down and discharged into the river by the drains during storms, when the surface of the city is washed clean of much organic deposit, and partly also to a small amount of sewage which, at least at present, it will be found preferable to discharge directly into the river from Ferry Point and near Fort McHenry.

Calculations were also made to show the displacement of the tidal prism by the upland minimum flow. Owing to the width of the river below the city, it is found that the gradual movement toward Chesapeake Bay is very slight, and that, if sewage were discharged into the river, it would be removed very slowly, and therefore cause objectionable conditions.

A disposal of the sewage of Baltimore by dilution, therefore, would mean nothing less than the building of a sewer to near North Point and of discharging its contents into the current of Chesapeake Bay. No point nearer the city and no smaller body of water, such as Back River, would prevent dissatisfaction.

North Point was suggested already in 1881 for this purpose by Mr. Charles H. Latrobe, C. E., in his "Report on a System of Sewerage for the City of Baltimore." This outfall was placed in about fourteen feet of water.

The channel in the bay is near the Eastern Shore, and no place having more than eighteen feet of water at mean low tide is found within two and a half miles of the Point.

It is, therefore, necessary to discharge the sewage into the comparatively shallow water of the bay and into a tidal current. A calculation with reference to the flow of upland water which would pass down Chesapeake Bay opposite North Point during extreme dry weather, based partly on observations and partly on deductions, is about 6,800 cubic feet per second. The ordinary minimum discharge is about 20,000 cubic feet per second.

Therefore, could the sewage of Baltimore be discharged into the current of the waters of Chesapeake Bay, it is safe to assume from what was said above that at the lowest figure applied to non-tidal streams, the sewage of about two and a quarter million people might thus be disposed of at the most unfavorable time.

The effect upon the oyster beds, so far as we are able to judge at the present time, is problematic. It is true that there is evidence showing the danger of having oyster beds near the sewage outfall. But, in case ill effects are positively demonstrated, and in case there were no other method of disposing of the sewage of so large and important a city as Baltimore, then it would be necessary to abandon as many of the oyster beds as would be subject to pollution.

In order to deliver the sewage at North Point it would be necessary to build an outfall sewer all the way from the city. Mr. Allen made surveys and profiles of several lines, as directed by us, from which after a careful study, the best one was selected.

Assuming a starting point on the Shell Road at Twenty-fifth street, the line extends to General's Point, there crosses Bear Creek by means of an inverted siphon, described below, and continues in an easterly and then southeasterly direction until it reaches a gate house at the shore, also described below, and thence is continued with a submerged outlet into the current of the bay.

A settling basin should be constructed at the upper end of the outfall sewer, to collect the sand and other solid matter which will settle. It is an underground chamber into which the outfall sewer discharges, and has two channels for the sewage, so that one channel can be in use while the other is shut off. Each channel should have a gate at each end, and one in the division wall between the two channels, for drawing off the sewage left in the channel between the gates when they are closed. A sump is placed in the bottom of each channel for collecting the sand.

A house is erected over this chamber with provisions for thoroughly lighting and ventilating the channels. A traveling crane and hoisting apparatus for cleaning out the sumps should be placed in this building, and the necessary tracks provided, on which small cars can receive the sand and deposit it at a dumping place.

The inverted siphon under Bear Creek has an underground chamber on the west shore from which two five foot nine inch brick conduits extend underneath the bottom of the creek to two vertical wells rising to an underground chamber on the east shore of the creek, out of which chamber the outfall sewer extends eastwardly to the outfall. In the chamber at the west shore a gate is placed in front of each siphon opening, and in the chamber at the east shore there are stop planks to allow either siphon to be shut off and pumped out in case of a break.

Both of these siphons should be built at once, but they are large enough to take the total amount of sewage estimated to flow in the outfall sewer when the city has one million inhabitants. In order that the smaller amount of sewage, which will be collected at first, may flow through the siphon at a velocity sufficient to keep sediment from depositing, only one of them should be used for present service. Then, in case of a break the sewage could flow through the other conduit. In order to provide for the remote contingency of a break in both conduits, an overflow pipe opens out of the side wall of the chamber on the west shore, through which the sewage can be discharged into the creek. A house should be erected over each of these underground chambers, having arrangements for thoroughly lighting and ventilating them, and for operating the large conduit gates and setting stop planks.

A settling-basin should be built at the bottom of the sewer, just west of the upper chamber, so as to keep whatever solid matter may have passed the main settling-basin from getting into the siphon.

A gate house is located on the shore of Chesapeake Bay, from which two outfall pipes extend into it about two and a half miles. As only one of these lines of pipes need be built for present service, two overflow conduits have been provided and extend to the shore of the bay, so as to discharge the sewage in case of a break or stoppage in the outfall pipes.

Gates are provided for these conduits, and manholes for their examination or repair. A retaining wall protects the gate house and overflow conduits from the sea. A house should be built over the gate chamber with provisions for lighting and ventilating it. The gates of the overflow conduits are operated from the floor of this house, and arrangements exist for raising and lowering each gate.

The route of the main collecting and intercepting sewers through the city is shown in detail upon the plan and profile which accompany this report.

The territory lying below the line of the gravity main intercepting sewer is served by low level interceptors, practically skirting the edge of the branches of the river and the harbor, one or two blocks from it, and collecting the sewage to a low point near the intersection of Lombard street and Jones' Falls. Here, a pumping station would be located, where the sewage could be lifted and discharged through a force main into the main intercepting sewer at Broadway and Lombard street.

The location of this pumping station was selected with reference to concentrating the sewage to the best advantage, and with due regard to economy both in constructing and operating the system.

The station, as shown on the plan, has been designed to contain a pumping plant of sufficient capacity to raise the sewage from the low level system to the high level interceptor, at the maximum rate of flow, when the city has one million people.

It has been estimated that the total amount of sewage from the low level system would amount to 32,250,000 gallons per 24 hours from about 215,000 persons, and assuming that one-half of this sewage is delivered in eight hours, the maximum flow into the pump well is at the rate of 48,375,000 gallons per 24 hours.

To pump this amount to the high level interceptor requires two 25-million gallon pumps, and a boiler capacity of about 500 horsepower. To have sufficient reserve power, this station is designed to contain three 25-million gallon pumps and three 250 horse-power boilers.

It is presumed that all of the low level intercepting sewers would be constructed in a few years, and that the construction of the District sewers and branches is extended over a much longer period. Therefore, it is estimated that the total amount of sewage for which present pumps should provide, is about 10,500,000 gallons per day, coming from about 70,000 persons. Assuming that one-half of this amount runs off in eight hours, the maximum delivery of sewage would be at the rate of 15,750,000 gallons per 24 hours. To pump this quantity to the high level interceptor requires one 25-million gallon pump and one 250 horse-power boiler. The station should therefore be provided at once with two 25-million gallon pumps and two 250 horse-power boilers.

The sewage from the low level system is brought to the pumping station through a 3 foot 6 inch main sewer from the south and a 2 foot 4 inch sewer from the north in Front street, and a 5 foot 6 inch sewer in Water street.

The two sewers first mentioned join near the pumping station, and the sewage from both is brought to the pump well through a 4 foot 6 inch sewer. The sewage from the 5 foot 8 inch sewer is brought under Jones' Falls to the pump well in a 4 foot 6 inch siphon tunnel. These two 4 foot 6 inch sewers are brought to a gate and cage chamber. After passing the gates the sewage flows through a screen cage, which collects the larger solid particles of the sewage. There are two such cages for each of the two main sewers, one in front of the other, so that when one is being cleaned, the other screens the sewage. A hoisting apparatus raises and lowers them. It is operated by an engine located at the end of the boiler room, and is so arranged that it can be operated by hand, if there should be an accident to the engine.

The screenings can be thrown into a car and taken to the boilers and burned.

From the cage chamber the sewage discharges into a screen well, from which conduits lead to the suction pipes of the pumps, in front of which are inclined composition-metal screens preventing the finer particles from entering the suction pipes. These are kept free and clean by raking from a platform in the well provided for that purpose. The screenings are also to be burned.

The screen well is accessible by a flight of steps and is lighted from overhead and thoroughly ventilated through a large brick conduit extending to a flue in the smoke-stack.

The pumps discharge into a 48 inch force main, which would extend out Lombard street to the high level interceptor.

The coal house would be large enough for storing about 100 tons of coal, and teams could be driven up the inclined driveway from the street in front of the pumping station, and the coal delivered through chutes in the side windows of the coal house.

The smoke-stack for this station would be about 100 feet high and five feet interior diameter of core. It is so arranged that an economizer could be placed in the smoke flue leading from the boilers to the stack.

In locating the intercepting sewers above mentioned, many difficulties were met, such as the crossing of Jones' Falls, Gwynn's Falls, the B. & O. Railroad Tunnel and numerous large drains, and solutions studied out so as to make the lines practicable and comparatively inexpensive.

The elevation of the water in the well at the pumping station was fixed at about 18 feet below mean low water, from which it was necessary to lift the sewage fifty-two feet, in order to discharge it into the high level interceptor and outfall sewer. The territory from which the sewage would require pumping, was estimated at about 3,550 acres, having a present population of about 183,000 persons, and an estimated future population of about 288,000 persons.

The sewage of the different parts of the city would be delivered by main sewers, suitably located to collect the sewage economically from each natural sewerage district.

J

PRECIPITATION.

Another method of disposing of sewage is to clarify it by the addition of certain chemicals, to let the clear water enter a stream and to put the settlings on land. When milk of lime, salts of iron or aluminum are added to the sewage, much of the organic matter contained therein is coagulated and gradually settles to the bottom. The supernatant liquid is thus cleared and relieved of a large portion of this organic matter. Experience shows that about one-half of the organic matter originally contained in the sewage can thus be precipitated.

To allow the sewage to deposit its suspended matter without the addition of chemicals is not advantageous. It is true that some of the heavier particles will fall to the bottom when the velocity of the sewage is reduced, or entirely ceases, but the process is slow and imperfect. It does not remove a sufficient quantity of the offensive matter to justify the expense of such a plant.

The precipitated sewage matter, or "sludge," must be artificially removed from the settling tanks and separately disposed of.

The treatment by precipitation consists in allowing the sewage to enter large tanks after it has received the proper quantity of chemicals, and to allow it either to rest, or to pass very slowly through the tanks, so that the suspended matter can settle to the bottom before the water leaves them. It is allowed to flow out over a weir as a thin sheet of water. There must be enough of these tanks to enable the sewage to pass through at a sufficiently slow rate, and to allow of a sufficient number to be out of use, while the sludge is being removed from them.

The disposal of the sludge is the most difficult part of the process of sewage precipitation. As it is in a semi-liquid form, the best method of dealing with it, under all but extraordinary conditions, is to pump it into so-called sludge presses, which remove the water and transform the sludge into solid cakes which can readily be disposed of. They can be used either for filling in land, or, where the expense of hauling is not too great, they have been profitably used to fertilize land, or they have been burned.

The best example of sewage precipitation in this country, and perhaps in the world, is at Worcester, Mass., with which works you are, no doubt, more or less familiar. The sludge has there been disposed of by pumping it upon land and letting the sun dry it. At present, however, arrangements are being made to erect presses and to transform it into cakes, as described above.

The advantage of a sewage precipitation plant, so far as Baltimore is concerned, is the circumstance that while the outfall sewer for a dilution project would have to be built at once with its full capacity, a precipitation plant need be built at first only of a size to accommodate the early flow of sewage, and then be gradually extended as the amount of sewage increased. Another advantage of such a plant would be its temporary use along the line of the discharge mains to the proposed filtration fields, and thus temporarily save the cost of preparing the latter and of pumping the sewage to so great a height.

The disadvantage of such a plant lies in the fact that its operation is somewhat expensive. It has been found in Worcester, where the works are managed with exceptional skill, that the annual cost of treatment, exclusive of laboratory expenses and sludge disposal, has been nearly 30 cents per head of population.

Considering this cost to be the same in Baltimore, and adding a proper amount for the pressing and disposal of the sludge, we have estimated, for such treatment in your city, an annual expense of thirty-five cents per head of population. If we assume a future population of one million inhabitants, the annual cost of precipitation, including sludge disposal, would then be $350,000.

When the clarified sewage is discharged into a stream, it must also be diluted in order to prevent subsequent offensive decomposition. But the dilution need not, of course, be so great as in the case of raw sewage, containing suspended organic matter which is much slower in yielding to oxidation.

It is uncertain how much of this sewage effluent may be safely discharged at the mouth of Colgate Creek or into the Patapsco River.

As the process removes only about one-half of the organic matter there is, under favorable conditions, still a cause left for offensive decomposition. In fact, in the absence of sufficient oxygen the dissolved matter yields even more rapidly to putrefaction than the suspended matter. But once exposed to oxygen it will also more rapidly be converted into inoffensive compounds. If, instead of 3 cubic feet per second, as above assumed in the case of raw sewage, we were to allow but one-tenth of this quantity, or 0.3 cubic feet per second of fresh water, to dilute the effluent sewage from precipitation tanks per 1,000 persons, the minimum flow of the Patapsco River, estimated above at 111 cubic feet per second, would be capable of receiving such effluent water from only 370,000 persons. To discharge the effluent from one million people during the late summer months, might therefore possibly become objectionable, particularly as no allowance has above been made for the effect of the pollution of the harbor by the shipping and by storm water discharge.

A precipitation project, as a permanent solution of the problem of sewage disposal for the city, should therefore require a discharge of the effluent water into Chesapeake Bay.

A convenient location for the precipitation works is on a tract of land lying easterly of the city, and on the southerly side of Fifth avenue, near the head of Colgate Creek, as shown on the map. Nearly 80 per centum of the entire sewage of the city can be brought to the works by gravity, while the balance will have to be raised about 52 feet by pumping.

The works have been designed to treat, for the present, an average of 50,000,000 gallons of sewage per 24 hours, or for a population of about 330,000 persons. There are 48 tanks required, 10 of which are 92.4 by 325 feet, 18 are 50 by 172 feet, and 20 are 50 by 150 feet; in all of them the sewage will average 6 feet in depth. The combined capacity of the tanks is 27,229,500 gallons, or a little more than 50 per cent. of the estimated present flow. They have been so designed that a part, or the whole of them, can be built at once; also, that additions can be made from time to time, as the flow of sewage increases. They will cover an area of 680 by 1,100 feet, or about 17.13 acres, including the channels.

The method of treatment suggested for the sewage, and for which the works were planned, requires the use of lime and sulphate of alumina as coagulants, and filter presses for treating the sludge.

Buildings have been planned to accommodate the necessary machinery to apply this method. They consist of a screen house, engine and boiler house, chimney and a sludge-press house.

The screen house, with a screen chamber and rack, is built over the main outfall sewer, so that all foreign substances may be detained and as often as necessary removed from the screen by rakes. These screenings are taken to the boilers and burned.

The boiler and engine house is 50 by 80 feet, with two floors. The boiler room is at one end of the lower floor, and the other end contains the engines, chemical mixers and electric motors. On the second floor are the chemical store room, laboratory and offices for the superintendent.

The sludge-press building, on the opposite side of the sewage channel, is 48 by 102 feet, single story, and contains the sludge pump and presses. It is devoted exclusively to this part of the work. A reservoir is placed under the ground at one end of this building, where the sludge is collected from the tanks previous to pumping it into the presses.

It is probable that a portion of the power needed for driving the chemical mixers and dynamos used for lighting, may be derived from the fall of the effluent as it is discharged into the creek. There is an available fall of about 10 feet, and assuming a daily flow of 50,000,000 gallons, there would be 87 gross horse-power, but as the discharge is extremely variable, it is not safe to estimate more than one-half, or about 40 horse-power. The balance required must be supplied by steam, and steam power is necessary for operating the various pumps.

Estimates of the amount of sludge that will be produced are based upon the assumption that for every 1,000 people 54 cubic feet of sludge may be expected, and that for the assumed population for present purposes 18,000 cubic feet per day will have to be taken care of. Twenty-two sludge presses and four sludge pumps are required for this amount. Ample capacity for taking care of the sludge should be provided, for upon its prompt removal depends much of the efficiency of such a plant.

For mixing the chemicals eight mixers are estimated. They are designed to run by independent electric motors; this method being much more simple than the older method of shafting and belts.

Several vats for slacking the lime are also provided in the building.

There are two 50 horse-power boilers, one engine and an electric dynamo; the latter is required both for transmitting power and for lighting.

Should the effluent water be used for power, a wheel-house and dynamo are needed near its outlet. The power could be brought through the engine room by wires and then distributed as needed.

The method of operating the works is as follows:

The sewage, after passing through the screen house, enters the mixing channel, where it receives the milk of lime, and a few feet further a solution of sulphate of alumina. After a thorough mixing by a mechanical device, or by flowing over and around obstructions placed in the channel, it then enters the gate house, where it can be diverted into either one of the various channels, and by means of gates, is first discharged into the larger or roughing tanks, where the bulk of the solids is deposited. From these tanks the sewage flows over a weir, at the farther end of the tank, into the influent channel. Skimming boards are placed in front of the weirs, to prevent solids from flowing over into it.

From the influent channel the sewage passes through gates into the smaller or finishing tanks, where the finer particles are deposited. From these tanks the clarified sewage flows over a weir into the effluent channel and thence to the creek.

The frequency with which the tanks require cleaning will depend entirely upon the amount and foulness of the sewage. Ordinarily the larger tanks require cleaning about three times a week, or every other day, while the smaller tanks are cleaned once or twice a week, as may be required. For this purpose the effluent water in the tanks is drawn off by means of skimming pipes placed at the farther end, opposite the inlet, and leading into the effluent pipes under the channels. It is discharged into the creek at a lower elevation than that discharged from the effluent channel.

The sludge, or what remains after drawing off the upper clear liquid, is then drawn back through special channels into the main sludge pipes, leading into the reservoir located at the end of the press house. From the reservoir the sludge is raised by pumps and forced into the presses, forming "sludge cakes."

Experience shows that about 90 per cent. of the sludge is water and the foul liquid which is separated from it by the process of pressing needs to be re-treated. To accomplish this, the presses are placed on a level above the mixing channel, so that the liquid coming from the presses can run back into it.

Water pipes connected with hydrants and conveniently placed, should be laid around the tanks so that they can be thoroughly washed after the sludge has been drawn out. The water for this purpose can be taken from the effluent channel and pumped directly into the pipes as needed, or a storage tank can be built at a sufficient height to give the required pressure.

The amount of chemicals required depends largely upon the character of the sewage, but it is generally considered that 8,000 grains of lime and 2,000 grains of sulphate of alumina are ample to properly clarify 1,000 gallons of average American sewage.

If the works are carefully managed there need be no nuisance about them, excepting at the tanks holding the sewage, and for which reason it is desirable to locate them in a neighborhood that is not populated.

The route of the main collecting and intercepting sewers is the same as for the dilution project previously described, and shown in detail upon the plan prepared for it.

If a precipitation plant is used for temporarily treating the sewage which is later to be purified by filtration, it may be located on the south shore of the Patapsco River, east of Brooklyn, or it might even be built on unoccupied land near Ferry Point. In either case, the works need not be built as permanently as recommended for the location at Colgate Creek. The tanks could be built of creosoted timber instead of masonry, and the temporary sewers leading thereto could be made of the same material. The buildings might also be built of wood. The estimates of cost have assumed timber to be used for these several structures.

K

FILTRATION.

Sewage can be disposed of also by filtration. If it is allowed to run through coarse material, such as broken stone, it will deposit a large amount of its suspended matter upon the stones and, dependent upon the quantity of sewage so discharged and the length of time in which it travels through this material, the sewage will emerge more or less purified. The stones, however, gradually become coated and require replacing.

For small amounts of sewage, such a system of filtration, which is little better than a straining, will sometimes answer. It will not answer for treating the sewage of a large population, under conditions which prevail in Baltimore. The expense of properly preparing such a bed of stone, and the attention which must be given to it in its management, and to its occasional replacing, altogether make such a system of disposal not only less perfect, but also more expensive than other methods, which are more extensively used and which will now be described.

When the sewage is turned upon a porous soil, pure sand being the best, it percolates through the same more or less rapidly, owing to the coarseness of the sand and to the head of sewage resting upon it. The first result of this percolation is a straining out of the coarser particles. As the water passes down, the subsequent result is to expose it to the action of bacteria, which, directly or indirectly, accomplishes the thorough oxidation of the sewage matter, so that, under favorable conditions, the escaping water at the lowest point of the filter will be freed from the objectionable quantity of organic matter and from the myriads of bacteria which are found in the raw sewage.

The Massachusetts State Board of Health, in its admirable work on the Purification of Water and Sewage, has demonstrated the favorable conditions for this purifying action, and, by a very extensive series of experiments with different kinds of soils and sands, has given the profession a means of judging what can be accomplished, without doubt, by filtering sewage of a known character through a material of a known character.

It was formerly thought that the best method of disposing of sewage on land was to have it absorbed by vegetation. This view caused many of the English sewage farms to be originally laid out solely for the purpose of crop raising, and it was held, for instance in Croydon, that the water of the sewage should either be evaporated from the surface or taken up by the crops, but not allowed to percolate through the soil. Therefore sub-drainage was not advocated.

While this process gave satisfaction when properly operated, it required a very large area of land per thousand persons. This large area was not always obtainable. In order to use a smaller area it was found necessary to sub-drain the land, and thus to free it of the water which had percolated into the ground. This water was found to be comparatively pure, and, in some instances, quite pure.

It was then proposed in England by Dr. Frankland to purify sewage by means of intermittent filtration, by which method the purification was accomplished, not necessarily through the aid of crops, but by the passage through porous soil. Intermittency was necessary, according to Dr. Frankland, so that the pores, which at one time are filled with sewage, are alternately filled with air, to supply the oxygen which is necessary to finally accomplish the purification. Intermittent filtration was first practically applied in England, by Mr. Bailey Denton, and its success was assured nearly twenty years ago.

The recent experiments of the Massachusetts State Board of Health related to intermittent filtration, as it was found that a continuous filtration of sewage through sand was absolutely void of satisfactory results, the sand then acting merely as a strainer and the sewage escaping with its dissolved organic matter not removed.

We are to-day in a position to state, not only that sewage can be thoroughly purified by filtration through porous soil, in percolating slowly and intermittently through it, but also that the fields can be arranged so that crops may be successfully raised, while at the same time the sewage is being purified.

The application of this method is, of course, only available where the necessary area of land of suitable quality can be had. A search on the eastern side of the Patapsco River to discover such land proved unavailing. On the western side, in Anne Arundel county, as has already been stated under Section C, there is an abundance of land which is well suited for the purification of the sewage of the City of Baltimore. It is shown on the U. S. Geological Survey Map which is appended, Plate M.

The distance to this territory is not greater than the distance to a sewage outfall at North Point into Chesapeake Bay. In fact, there is a large area of suitable land somewhat nearer. Some of the territory is at present covered with timber and some of it is under cultivation.

With reference to disposing of sewage on land, it should be stated that no nuisance need arise from the same. When delivered from a well-managed sewerage system it is supposed to be comparatively fresh, and should have but a slight odor. But, even if it has an odor when delivered upon the fields, it is found that after it has been distributed and has filtered away there is practically but little, if any, offense.

From the samples of soil taken from the proposed filtration areas at Glen Burnie, it will be safe to estimate, according to the locality, for a disposal of from 10,000 to 25,000 gallons of sewage per acre per day, without stripping off the top soil. If it is all taken off and only sand remains to receive the sewage, this area will probably purify from 30,000 to 50,000 gallons per acre per day. The territory north of Furnace Creek is on the average not as good as the area south of it. It would be well to assume the lower of the above figures for it.

Assuming that 500 acres are available north of the Creek, we can therefore dispose upon it 15,000,000 or 5,000,000 gallons daily, according to whether the top soil is removed or not.

Assuming that south of Furnace Creek there are 1,000 acres available, we could on the average dispose of 40,000,000, or 15,000,000 gallons of sewage daily, according to whether the top soil is taken off or not.

There are large areas of timber land, some orchards and some marsh land on this territory, some of which can be made available if necessary, as beneath a surface layer of from 6 to 12 inches in depth coarse sandy soil is found.

The Elvaton filtration area comprises the territory of Marley Neck and Tick Neck and other lands down to Magothy River. It is better adapted for sewage filtration, because the sand is almost free from loam. We think it will purify about 25,000 gallons of sewage per day without stripping, and perhaps as much as 50,000 with stripping.

There are about 8,000 acres available on this territory. After a thorough preparation and removal of the surface layers of soil, the Elvaton area may therefore take as much as 350,000,000 gallons of sewage daily.

From the above it will be seen that there is within a reasonable distance of Baltimore a large territory available for the purification of sewage. In fact, there may be as many as 10,000 acres obtainable above the Magothy River, which altogether would answer for purifying the sewage of more than two millions of people. Both the cities of Paris and Berlin are obliged to carry some of their sewage further off before proper territory for purification is reached.

The Glen Burnie area is shown on one of the maps, Plate H, together with a general outline of the way in which it can be adapted for sewage filtration.

In order to get the best results, the ground must be stripped and freed from the top layer of soil. A proper system of distributing the sewage should be laid out so as to utilize the ground at all times to the best advantage.

The ground of each bed, which should contain about one acre, should be leveled, and generally provided with ridges and furrows so that the sewage may flow over it uniformly and not accumulate at some low point which would overcharge a portion, while another portion receives an insufficient quantity. The ground must also be thoroughly under-drained, because the water, after percolating through the sand, must be rapidly removed in order to permit of a proper intermittent aeration, and thereby secure the maximum duty.

Before the sewage is allowed to spread over the fields, it may be advisable, and it is sometimes necessary, to screen it so that there will be less deposit upon the fields. Occasionally it is even advisable to allow much of the heavier matter to deposit in tanks before the sewage is turned upon the fields. A larger quantity can then be filtered per acre of ground. But this expedient will probably not be necessary in this case, as there is no scarcity of land.

Regarding the raising of crops and operating a sewage farm, it is best to start tentatively and to ascertain the best methods of cultivation and management for the local conditions existing in your neighborhood. Some crops do better than others. Some will use up more sewage than others. Some are more profitable and find a more ready market than others.

Vegetables should be grown upon ridges and protected from a direct contact with sewage, just as it is undesirable to bring them in direct contact with manure.

Ensilage is meeting with success in Europe, and if you find it practicable and economical to raise large crops of grass, it would be well to experiment with regard to preserving the grass in the manner which is profitable in England.

Well-managed sewage farms do not create a nuisance. Residences of well-to-do people are found in the neighborhood of such farms in England, and in a few instances also on the continent of Europe. In Berlin there are several homes for convalescents from hospitals in the midst of the sewage farms, and some other similar institutions are intended to be placed there. The death rate on large English sewage farms, according to Baldwin Latham, in 1880, was but three per thousand. On the Paris and Berlin farms it is similarly low. In the City of Baltimore it is now over twenty per thousand.

Fish breed freely in the effluent water from the Paris and Berlin and the best English sewage farms.

The manner in which the sewage of the city may be collected and delivered at the disposal areas is shown on the plans. The Glen Burnie area is about six miles from Ferry Point and the Elvaton area is about ten miles from the same. The elevation at which the sewage can be distributed on the nearer territory is 55 feet and on the farther territory 80 feet above datum.

It is desirable, of course, to deliver as much sewage as possible upon these areas by gravity. We find that about one-third of the assumed population, namely, about 365,000 persons, will eventually reside upon territory which is sufficiently high to deliver its sewage upon the Glen Burnie area by gravity. It is not practicable to deliver any of the city's sewage at Elvaton by gravity.

At Glen Burnie there are about 1,400 acres upon which sewage may be purified, about 200 acres of which lie west of the discharge mains. Therefore, if we estimate an acre to purify 40,000 gallons per day, the Glen Burnie territory is just about sufficient to receive the sewage that can eventually be delivered by gravity. The sewage of the remainder of the population will have to be pumped and eventually delivered on the higher Elvaton area.

Until the population of the city discharging its sewage into the system exceeds about 350,000 persons, all of it can be delivered to Glen Burnie, which will postpone the preparation of the higher area for a number of years, and also the laying of the separate discharge mains leading to it.

We therefore advise that the Glen Burnie area be prepared first, and that it be used for all sewage delivered until its full capacity has been reached, and thereafter that the Elvaton area be prepared.

The method of collecting and delivering the sewage upon the filtration areas will be described further on.

L

COMPARISON.

In making a comparison between the above-mentioned three possible methods of disposing of the sewage of the City of Baltimore, we should consider the preference both for future and for present conditions.

The methods of disposal are the discharge of crude sewage into the deep water of Chesapeake Bay, the discharge of clarified sewage into the Patapsco River and eventually into Chesapeake Bay near the shore, and the purification of sewage by filtration in Anne Arundel county.

The difference in cost between these methods is in our opinion not sufficient to decide the question of preference. We believe that it should be decided upon other grounds.

When we consider that there is a practical way of quickly and thoroughly purifying the sewage of Baltimore without creating a nuisance, and at the same time utilizing it for irrigating lands which to-day have but a small value for agriculture; when we consider that a discharge of crude sewage into Chesapeake Bay does not at once effectually dispose of it, but allows it to oscillate with the tides in the navigable waters and over present oyster beds before it is thoroughly dispersed; finally, when we consider that the effluent from a precipitation plant is but clarified and not purified sewage, and that there is insufficient flow in the Patapsco River to properly dilute it when the city has grown to about double its present size; we have no hesitation whatever in recommending the purification of the sewage upon the sandy territory in Anne Arundel county, as the best solution of the problem for all time.

We consider the city, in fact, to be unusually fortunate in possessing sufficient suitable territory so near its limits. There is hardly another large city in the country which is equally favored in this respect. No experiment will be made in thus disposing of the sewage, as experience has been obtained in thus dealing with it for nearly half a century. From Berlin and Paris, which have the largest sewage filtration fields, down to the many smaller cities in England, and also in several cities and towns of our own country, the process has been tried and developed so that it is quite safe to predict the results obtainable under given conditions, and to prevent any possible failure. To reach a successful result it is merely necessary to apply existing and obtainable knowledge to the preparation of the filtration fields and to their subsequent operation.

We feel certain that the purification of sewage by land filtration will be found a far more satisfactory disposal in your case, than either the partial purification by chemical means, or the crude disposal into the Bay. Filtration is likely to settle the question for all time, just as it has so been settled in many other cities, while with the less perfect purification, future trouble is apt to arise in your case, pointing to the possibility of eventually changing the method and incurring further expense.

While we are of the opinion that a disposal by filtration is the best method for your city to adopt in the future, we believe it is also best at first. The crude disposal system requires at once the construction of a large outfall sewer to North Point. It would have to be built of a capacity answering for a distant future, which capacity would therefore not be required for a long time. The precipitation plant could be built with a small capacity at first, but there remain the other facts that the sewage is merely clarified and not purified, and that no use can be made of the effluent water. The filtration system at once purifies the sewage and utilizes it for irrigation. It need be laid out at present only sufficiently extensive for the quantity of sewage which it is to receive. Its area can be increased gradually, which thus avoids a large investment of money at the outset. A further reduction in the first outlay could be made by a temporary chemical treatment along the western shore of the Patapsco River. The expense of the discharge mains to the filtration fields and the cost of preparing the latter, would be saved until the precipitation system had reached its capacity.

After having presented our conclusions, which advocate a final disposal of the sewage by filtration in Anne Arundel county, it is now necessary to inquire into the methods to be adopted for collecting the sewage from the city and delivering it at the proposed fields.

M

METHODS OF COLLECTION.

There are in use several methods by which sewage can be collected in a city and taken out of the same. In every case there are, of course, pipes or sewers which conduct the sewage from the houses to the street, and then along the streets to a pumping station or to an outfall. As the rain-water must usually be carried off in a similar manner, it has been found economical in large cities to carry the sewage and rain-water together in the same channels. This is done with the so-called *combined* system.

There are cases, however, where it is not economical to build sewers to carry off both these waters. In smaller cities it is customary to allow the rain-water to run off on the surface of the streets, so far as practicable, as such surface removal usually does not interfere with traffic, nor is it otherwise objectionable, and it saves the expense of large sewers. In such cases, the sewage alone is taken away in pipes, and not mingled with the rain-water. This is usually called the *separate* system.

There are still other conditions where this system is preferable. Where it is necessary, for instance, to pump the sewage, the admission of rain-water necessitates a much larger plant for pumping, much of which is in use only during storms. In almost all cases it is possible to allow rain-water to run off by gravity into natural watercourses, and therefore to avoid pumping. To combine it with sewage when the latter requires to be lifted, is usually not economical.

Again, where it is necessary to give the sewage some treatment, *i. e.*, to purify it either by the chemical or the land treatment, it will be evident that if rain-water is admitted to the sewers, a much larger quantity of water must be dealt with, and therefore the expense of treatment is materially increased.

When a combined system is used, it is however always understood that, when sewage is either pumped or treated, all of the rain-water is not subjected to this handling. There are overflows provided in the sewers which allow any excessive storms to discharge their water into natural watercourses. The water of slight rains only is allowed to remain with the sewage, and it is usually proper to allow this quantity of water to be about double the greatest flow of sewage.

The admission of rain-water to this extent has frequently been advocated, because the first wash from the streets contains a good deal of waste organic matter. Where a pollution of the water-course, due to such washing of the street surfaces, is objectionable, it is proper to have the rain-water disposed of in such a manner.

In some cities a provision for rain-water removal has been made and drains have been built before the question of sewage disposal became urgent and demanded a solution. If such drains are fairly good and of sufficient capacity to take care of the rain-water, then, when the removal also of foul water is required, it is usually found best, for economical reasons, to adopt the separate system.

N

SEPARATE SYSTEM.

The City of Baltimore being provided with drains to a large extent and at a great cost, and most of such drains being fairly well built and efficient for their purpose, is one of those cities in which the separate or double system is preferable.

It may be added that some years ago it was urged that a separate system was preferable in all cities, from a sanitary point of view, and that it should be introduced in all large cities, even if it required a complete double system, one for sewage alone, and the other for rainfall alone. The arguments then made have, however, not been substantiated by facts, because it was found that the cities which had a combined system, well built and carefully managed, generally had a lower death rate than before such systems were introduced, and that other cities, adopting a separate system of sewerage had no lower death rate, and, in at least one instance, even a higher rate than in cities where the other system was in use.

There is no reason, either theoretical or practical, why a separate system should be preferable from a sanitary point of view, and, therefore, the question of preference between the two systems should always be decided on the basis of cost. In Europe we find the separate system in use only in a few English cities. In America it is used more frequently, and, therefore, the experience gained with it here has been greater. There are no large cities where it is as yet used, however. The City of New Orleans has adopted it, and the system is under construction, but not yet in use.

The conditions existing in Baltimore are peculiar, and different from most other cities as regards the sewerage question, and therefore it is necessary to examine it carefully and independently.

The existence of an expensive system of drains for rain-water removal, the necessity for treating the sewage, as has already been stated, and also the necessity for pumping most of the sewage of the city, argue for the adoption of the separate system more strongly than in any other large city in the United States which has not yet been provided with a modern system of sewers.

It may be mentioned here that Mr. Charles H. Latrobe, C. E., in his able report upon the sewerage question in the City of Baltimore in 1881, recommended the separate system.

There is a certain flexibility in such a system, as regards the admission of rain-water. In England, where it is used in a number of smaller cities, it has been urged that a portion of the rain-water should be admitted for the purpose of flushing the pipes. It is there customary to allow the rain-water falling upon the back roof of the house, and sometimes also that falling upon the back yard, to enter the separate sewers. The advantage of this custom lies in the fact that the increased flow through the sewers gives an admirable flush. The water entering at all their heads simultaneously, causes a flush, not only of the laterals, but also of the main sewers.

In England the rainfalls are not as intense as they are in this country, and a provision to admit their water as described, therefore, does not require such a large additional capacity as would be necessary in Baltimore. In the United States, it has been practiced in many cases, to admit only roof water for the above purposes, and it has been found to be an advantage whenever the arrangements have been proper.

The difficulties to be met are in the limitation of the amount of water which thus enters the sewers from each house, and also in the limitation regarding the number of houses allowed to discharge their roof water into the sewers. It is evident that the advantage to the system is obtained only from the water admitted near the heads, and that the roof water lower down in the system should be excluded. As such a discrimination is not always practicable, it is also customary to accomplish the same end by flush tanks, usually placed at the heads of the lateral sewers, and discharged either automatically or by hand.

The advantage to be expected from flushing the upper ends of the sewers is the removal of deposits, due to the fact that the sewage flow is not only slight, but also intermittent, and therefore permits such deposits to form. Lower down in the system, after receiving the sewage from many laterals, there is a constant flow, and if the sewer is designed to cause a sufficient velocity and a proper sectional area, deposits are not usual, and are due only to an extraordinary occurrence, which makes it necessary to remove the deposit or obstruction by special means.

It remains now to describe the principal features of the sewerage system as recommended to you; to follow it with a description of a drainage system for the city, and to conclude with an estimate of cost.

O

PRINCIPAL SEWERS AND DISTRICTS.

The methods of disposal recommended, being a filtration upon land in Anne Arundel county, it is necessary to collect the sewage and deliver it to this land in the most economical manner.

As already mentioned, the elevation of part of the area that can be used, is sufficiently low, so that some of the sewage can be delivered there by gravity. It is, therefore, economical to divide the city by a high level intercepting sewer, collecting all the sewage which can flow by gravity to this area.

As a large portion of the territory over which the sewage is taken to the disposal area lies below the hydraulic gradient, it must be carried in pipes under pressure.

The remaining part of the city, lying below this gradient must have its sewage collected by a low level interceptor, situated as near to the shore line of the river as possible. Owing to difficulties of construction and expense, there will be some small areas along the water front that cannot discharge into the interceptor without special pumping, but may discharge into the river. As the amount of sewage is small, it cannot be objectionable in the harbor, when compared with the pollution caused by the shipping interests.

After some study, it was found best to locate the lowest point at which the sewage of the low level interceptor is collected near the intersection of Leadenhall and Stockholm streets. This point is convenient for collecting the sewage, and for receiving coal, and is therefore a suitable location for a pumping station, where the sewage can be forced into the discharge mains leading to the filtration fields.

As the amount of sewage to be collected in the high level interceptor will, for a long time, be comparatively small, and as a large portion of the population resides at an elevation which is much above that through which the low level interceptor is carried, it has appeared that a mid-level or intermediate interceptor might be an economical feature of the system. It would prevent a large portion of the sewage from flowing down to the lowest point to be again raised by pumps.

A general location for such an intermediate interceptor was made, and also a calculation to determine whether there would be economy in its adoption. The result showed that the mid-level interceptor project did not save expense.

An advantage would be its temporary use for collecting the sewage from the high level territory, thus for a while saving the building of the high level interceptor. This advantage, however, was not material.

A disadvantage, on the other hand, was found in a greater complication of the works at the pumping station, due to a separate set of engines, and in the necessity of increasing the initial outlay for the system, while without it it is only necessary to pay annually a sum for pumping the sewage to the additional height.

For present needs it is unquestionably cheaper to pump the smaller quantity of sewage obtained from the higher territory, than to build the mid-level interceptor at a cost which is intended to provide for the population of the future. Pumping machinery is continually being improved, reducing the cost of pumping so that it is rather probable than otherwise that the economy now apparent for pumping the sewage will become still greater.

It should be added here that a mid-level interceptor may form a means, in the distant future, of increasing the capacity of the sewerage system of the city upon the area it now occupies, in case such increase should ever be necessary. It is impossible to foresee the precise development of a city, and if, in many years, the low level interceptor should be found too small to do the work which with present foresight may be expected from it, then, without interfering in any way with the use of works that are now built, it would be more practicable to add a mid-level interceptor than at the present time. We therefore do not recommend its construction.

The entire area of the city has been divided into separate and distinct sewerage districts, some of which have their sewage discharged into the upper and others into the lower interceptor. The boundaries of these districts are shown upon the plan, Plate G. In each one the sewage is generally collected by district main sewers which eventually discharge into the respective interceptors.

These districts are usually identical with the natural drainage areas. Towards the northeast there is one, the Herring Run district, which naturally does not drain into the Patapsco River, and from which the sewage must be intercepted in order to be united with the rest of the sewage of the city.

The boundaries of the districts as marked can, of course, only be approximate, and will have to be adjusted later when the details of the system are elaborated. The alignment of the intercepting and main district sewers, as marked upon the maps, is likewise only approximate and will require further adjustment.

The route of the high level interceptors is as follows:

From the intersection of Eutaw and Franklin streets, where the interceptor discharges into gravity discharge mains which lead to the filtration fields, the eastern interceptor extends in a northerly direction to the intersection of Mount Royal avenue and McMechen street. It then crosses the valley of Jones' Falls by means of a pair of inverted siphons. These siphons cross in a tunnel sufficiently below the level of Jones' Falls so as to be in rock. They consist of iron pipes carried down the shaft, through the tunnel and up again in a shaft at 21st street (Plate J). It is better to carry the sewage across in special pipes than in a brick-lined tunnel itself. In the latter case there would be too small a velocity at first, owing to the large sectional area, and if reduced in area the necessary velocity in the future would consume too much head. The tunnel may be used also for other purposes. From the siphon the interceptor continues on 21st street to Hargrove alley, thence on North avenue and Barclay street to 20th street. It crosses the Jenkins Run valley by another pair of inverted siphons and then takes a southerly route on Ensor street to Hoffman and Preston streets. At Caroline street it again turns north and, as shown on the plan, reaches North avenue at Broadway, near which it terminates. It can receive the sewage from practically all of the territory lying between it and the southwestern boundary of the Herring Run district.

There is a small area in the Jenkins Run valley, north of North avenue, from which the sewage cannot be taken into the high level interceptor. This sewage will have to be carried south of North avenue and discharged into a low district sewer along Jones' Falls which discharges into the low level interceptor.

The sewer has been given a gradient so as to secure a mean velocity of three feet per second, east of Jones' Falls, and a velocity of four feet per second west of Jones' Falls.

It may be possible, when working up the details of the system, to slightly lower this eastern high level interceptor and thereby decrease the length of the siphons across Jenkins Run.

The western high level interceptor, beginning at the intersection of Eutaw street and Druid Hill avenue, extends, as shown on the plan, with many changes of direction which are necessitated by the topography and the layout of the streets, to the intersection of Pratt street and Fulton avenue. It is located on Pratt street for several blocks and at Pulaski street extends in a northwesterly direction into the valley of Gwynn's Run, which it ascends and terminates where its gradient strikes the level of the run.

This interceptor will receive all the sewage north of it and from both sides of Gwynn's Run valley north of the crossing of the Baltimore and Potomac Railroad.

As it is uncertain whether it will be desirable in the future to discharge the sewers, built in Gwynn's Falls valley, into the high level or into the low level interceptor, or into neither, both of them are made large enough to receive the sewage from such territory. The increase of size is inconsiderable.

The district mains of the upper system should naturally be carried down through the lowest part of the area. In many of them the streets are not yet laid out, so that no attempt was made to suggest the lines upon the plan.

As Druid Hill Park extends to the western side of Jones' Falls valley, and as between it and the crossing of the high level interceptor practically no sewage will have to be disposed of, it is deemed sufficient to place a main district sewer only on the eastern side of Jones' Falls. At Woodberry a branch can be carried across the Falls to a district which drains towards it.

There is a large quarry below the mouth of Stony Run and also other features which require a detailed study to determine the exact line along which this district sewer can be carried to the high level interceptor. If unexpected difficulties should arise, it will be necessary to at least temporarily discharge it into the low level system. There are no streets available upon which to place this sewer, and its location will therefore largely be a matter of procuring a right of way. It will be necessary to cross Stony Run with an inverted siphon.

The route of the low level interceptors is as follows:

From the pumping station at Stockholm and Leadenhall streets the eastern low level sewer extends on Leadenhall to Montgomery and thence to Charles street. It follows Charles street northerly to Balderston street and thence takes an easterly course on different streets, as shown upon the plan, to Jones' Falls, which it crosses by inverted siphons. It then takes the most available course to reach the intersection of Aliceanna street and Boston street, along which it skirts the Northwest Branch to Clinton street, the first street east of the city line. On Boston street it crosses under the Harford Run Intercepting Drain by means of inverted siphons.

From Clinton street this low level interceptor can be carried, as shown upon the plan, to Eighth street, thence northerly so as to cross the valley of Gorsuch Creek at Bank street. From this street it is practicable to continue the interceptor northerly with a fairly direct line so as to intercept the sewage from the Herring Run district. From Bank street it is also practicable to extend the low level interceptor so as to collect a large portion of sewage naturally draining into the valleys of both Gorsuch and Colgate Creeks as likewise shown upon the plan.

The area lying below the territory thus intercepted, and which at present lies outside of the city, in Canton, can in the future have its sewage conducted to a special pumping station situated at Gorsuch Creek, and pumped into the above-mentioned low level interceptor. When computing the size an allowance has been made for this contingency.

It is too early to suggest any definite project for collecting the sewage from the northeastern corner of the city which naturally drains into Herring Run. The territory is as yet undeveloped. Should it require sewerage, there are two possible ways of treating this area. The separate system should, of course, be adopted, because the sewage should be discharged into the general system of the city, while the storm water should flow into Herring Run.

It is practicable to collect the sewage of this area and to pump it from the lowest point into the high level interceptor on North avenue. It is also practicable to collect it at a low point and discharge it by a gravity sewer into the low level interceptor. The latter solution is indicated on the plans. From the fact that the territory has not yet been improved, we are obliged to limit our suggestions to these alternate and general solutions of the problem.

Owing to the uncertainty of how it will be found best to treat this area, we have made allowance for sufficient capacity to receive its sewage, both in the eastern high level and low level interceptors.

The western low level interceptor begins at the pumping station, extends out Stockholm to Russell street, and thence out Russell to Putnam street. At this point it branches. One branch extends southerly, crosses Gwynn's Falls and intercepts the sewage from the territory lying south of it, which though not within the city limits to-day, may be eventually annexed and require facilities for sewage disposal. The other branch extends northwesterly on the best available line to the mouth of Gwynn's Run. It can then be continued to the valley of Gwynn's Falls, as indicated upon the plan.

The Bush street drain which crosses the line of this interceptor will be crossed so that no inverted siphons are required.

Regarding the territory west of Gwynn's Falls, we are at present able to make only some general suggestions. It is much broken up by valleys and is not yet regularly laid out with streets. When this section of the city needs sewerage, it is practicable to adopt either of three general plans.

It is possible to collect most of the sewage of this territory by means of inverted siphons carried across the valleys of both Gwynn's Falls and Gwynn's Run, on or near the line of Baltimore street, and to discharge it into the high level interceptor. It is also possible, and it may be less expensive, to collect the sewage and to carry it down the valley of Gwynn's Falls and discharge it into the low level interceptor at Russell street.

Inasmuch as we are unable to decide which of these two propositions may be found most expedient when it is necessary to sewer the territory west of Gwynn's Falls, we have allowed an increase in the capacity for both the western high level and low level interceptors for this purpose.

There is a third possible way of sewering this section. When it becomes well built up and when the territory lying south is no doubt also being improved, it is practicable to build an intercepting sewer from Irvington direct to the proposed Glen Burnie filtration area. This sewer will then serve the territory of the present settlements of Claremont and Mt. Winans.

We have not estimated the cost of the western low level sewer further than to the far end of Russell street, as it is somewhat uncertain as to how the line should be placed at such a time when this sewer may be constructed. We have, however, shown a possible extension by a dotted line.

Likewise, owing to the uncertainty regarding the exact location, we have estimated the cost of the eastern low level interceptor up to the city line at Clinton street. By a dotted line, however, we have shown a possible way of extending it into territory which, in the future, should be sewered by it.

Locust Point is provided with main sewers as follows:

An interceptor starts at Charles and York streets, extends easterly on the latter, and skirts the harbor as far as the intersection of Jackson and Clement streets where it terminates.

Starting at the pumping station another intercepting and main sewer extends southerly on Leadenhall to Barney street, thence on Race to Winder street, thence through a rather deep cut easterly to Allen street. It crosses the peninsula on Allen street to Clement street and thence follows the latter to the intersection of Garrett avenue, where both the sewer and the present built-up part of the district terminate.

It is also practicable to extend this sewer southerly as far as Jephson street and there to cross the eastern part of the peninsula. It is also practicable, instead of placing the main sewer on Clement street, to build one on Wells street and another on Marriott street.

Neither of these lines is low enough to take the sewage from Fort McHenry or Ferry Point. It is considered that this territory which is excluded, may not require sewerage for many years. But whenever it is necessary it will be practicable to discharge the sewers directly into both branches of the river, by carrying them out to the heads of piers or through submerged pipes.

It is possible, by placing the interceptors on Locust Point at a lower elevation, to sewer the entire area as far as Fort McHenry. The cost of lowering the system, however, is much increased, both for construction, and also from the fact that all of the sewage, even that from the high territory of the Point, will at once have to be lifted to a greater height. The area which is now left out is small. It comprises, besides the Fort, but a small area not at present built upon. From what has been said about the capacity of the river to receive sewage during dry weather and under the least favorable circumstances, without causing trouble, we believe that this small quantity can eventually be discharged into it without harmful results.

Should such discharge not be deemed desirable, it is also practicable to discharge into the above-described main sewers or interceptors, by collecting the sewage at convenient points and there lifting it into them by automatic pumps, operating either by electricity or compressed air.

Between the two lines just mentioned, we give the preference to that which is more direct, because by saving the grade it reaches a greater distance and can collect the sewage from as far east as Garrett avenue, which is not practicable by the other line. The expense may be somewhat greater on account of the deeper excavation on Winder and on Clement streets, but this extra cost should not stand in the way of building a system which will effectively drain the largest possible area. The limit of the area is marked upon the plan, provided the street grades are favorably established.

The approximate location of the proposed upper district mains is indicated upon the plan. It will be noticed that a large main extends along the eastern boundary of Patterson Park. If found preferable, it can as well be located within the Park. District mains extend northerly from the interceptor on each side of Jones' Falls. Along a large part of the distance there is no street and the sewer will have to be carried along the railroad and a special right of way will have to be obtained therefor. In the low ground of the southwestern part of the city it will be well to place the main sewers more frequently so as to give the laterals sufficient fall. In order to collect the sewage from south of Winder street it will be preferable to build only a few district mains, as shown, into which the laterals discharge, rather than to carry these laterals on every street directly into the Winder street main.

On territory where streets are not yet laid out, it is advisable to make a careful study both of the sewerage and drainage requirements of such territory, and, if possible, to have the streets laid out in a manner which may not only serve the property, but also reduce the expense both of the sewerage and drainage of such territory. By considering the lay-out of property, with reference to these eventual requirements, it is often found that the total cost of improvement is much reduced.

P

PUMPING STATION AND DISCHARGE MAINS.

The pumping station has been provisionally located at the intersection of Leadenhall and Stockholm streets. The site should be selected not only with reference to collecting the sewage to the best advantage, but also with reference to economy, in the purchase price of the land, in the construction of the work and in operating the system.

The station has been designed to contain a pumping plant of sufficient capacity to raise all the sewage collected from the low level system, and to deliver it to the filtration fields at the maximum rate of flow in the intercepting sewers, at a time when the population of the city contributing sewage has reached one million persons, and also to contain a small plant for pumping the ground water, delivered by the sub-drains of the low territory, into the Patapsco River.

It has been estimated that the future total amount of sewage of the low level system will amount to 95,250,000 gallons per 24 hours, coming from 635,000 persons; and it has been assumed that half of the sewage will be delivered at the pumps in 8 hours, or at the rate of 142,875,000 gallons in 24 hours. In addition, a small allowance has been made for ground water, which may find its way into the sewerage system, to the extent of 1,500,000 gallons in 24 hours. The total quantity to be pumped to the filtration fields will be 96,750,000 gallons in 24 hours, at a maximum rate of 6,015,417 gallons per hour, or 144,370,000 gallons per 24 hours.

The elevation of the invert of the sewers at the pump wells is assumed at —13.75. The elevations to which the sewage must be lifted are + 81 for the Glen Burnie pipes and + 119 for the Elvaton pipes. The actual lift, when the sewers run half full, will therefore be 90 feet to Glen Burnie and 128 feet to Elvaton. As all pumping in the future will be confined to the sewage delivered at the Elvaton fields, the pumps should be proportioned for the greater lift.

The length of the gravity mains from Franklin street to Glen Burnie is about 55,050 feet, the length from the pumping station being about 37,900 feet. The length of the force mains to Elvaton is 57,000 feet.

To lift the above-mentioned quantities the station must eventually provide five 30,000,000 gallon pumps and a boiler plant of 4,100 horse-power.

The ground water collected at the station will be suitable for condensing the steam from the engines, and may be used for that purpose. But occasions might arise which necessitate its discharge into the Patapsco River. It would then have to be pumped against a head of 22 feet at the rate of 3,000,000 gallons per 24 hours, requiring one 3,000,000 gallon pump.

As there should be reserve pumps and boilers for the sewage and also for the ground water, the station has been planned to contain eventually six 30,000,000 gallon pumps, two 3,000,000 gallon pumps and ten 500 horse-power boilers.

It is presumed that all the low level intercepting sewers will be built within a few years, and that the building of the district sewers and branches will be extended over a much longer period. Therefore it has been estimated that in the low level system a present provision should be made for the sewage of only 260,000 people. The amount of sewage from this population, together with the ground water, gives a maximum rate of delivery at the pumping station of about 60,000,000 gallons per 24 hours.

To deliver this amount to the Glen Burnie filtration fields requires only two 30,000,000 gallon pumps and a boiler plant of 1,275 horse-power. Adding a reserve pump, then the station should at once be provided with three 30,000,000 gallon pumps for sewage, and with two 3,000,000 gallon pumps for ground water, altogether supplied by four 500 horse-power boilers.

The sewage of the low level system is brought to the pumping station through a 9 foot 6 inch main sewer extending northerly in Leadenhall street and a 4 foot 10 inch main sewer extending southerly in Leadenhall street, and a 6 foot 2 inch main sewer extending westerly in Stockholm street.

The two sewers last mentioned are connected at the corner of Leadenhall and Stockholm streets, and continue to the pumping station as an 8 foot 2 inch sewer. This and the 9 foot 6 inch sewer are brought together to a gate and cage chamber, where gates provide for shutting off the flow of sewage in either one or both of these large mains, in case of an accident to the machinery at the station. After passing through the gates the sewage is discharged into a well, across which four steel cages are set, with screens made of steel rods, for collecting the larger solid particles of the sewage. A hoisting apparatus, operated by an engine and located in a room adjoining the chamber, is set above these cages, to raise and lower them, when they become so filled with the solid matter as to impede the flow of sewage. The apparatus is so arranged that it can be operated by hand, should any accident occur to the hoisting engine. The screen-cages are hooked to a hoisting bar balanced by counter-weights, so that either one or all of the cages can be raised at once.

Steel screen gates are set in front of each cage and closed so as to screen the sewage while the cage is being cleaned. They are hinged to the screen-cage guide posts, and so constructed that they can be operated from the floor of the house. The screenings can be thrown into a car running on a track from the cage house to the boilers and be burned.

From the cage chamber the sewage discharges into a screen well (a large underground chamber), out of which conduits lead to the suction pipes of the pump. There are six of these conduits grouped in pairs. In front of each group is an inclined screen-rack of composition metal, to prevent the finer particles in the sewage from entering the suction pipes. These racks are kept free and clean by raking from a platform in the well provided for the purpose. The screenings are placed in a receptacle, carried to a shaft which opens into a room adjoining the boiler house, raised in it to the upper floor, dumped into a car and taken to the boilers and burned. Access to this screen-well is provided by a flight of steps. It is lighted from overhead and thoroughly ventilated through a large brick conduit extending from near the top of the well to a flue in the chimney.

The conduits leading from the screen-well to the suction pipe are lower than the bottom of the well, so as to insure a sufficient depth of sewage for supplying the pumps at times of minimum flow.

At the head of each conduit a gate is placed to control the flow, and also to shut off the conduit from the screen well, in case of an accident to the pump. These gates are operated from the yard at the side of the engine house, and can be readily reached through the side door in the engine room.

The large sewage pumps discharge into a 48 inch main laid along the side of the engine house, and from which four 48 inch force mains extend to the discharge mains in Hanover street. Only two of these, however, will be needed for present service. The gates in the 48 inch main in the engine house are arranged so that additional pumps can be connected with it in the future, without interfering with the running of the other pumps, and also in such a manner that the remaining two lines of 48 inch mains can be laid and put into service at any time.

The condensers for the large pumps are set in the basement of the engine room, which are lighted from the basement court area in the rear of the engine house. The condenser pumps may be arranged so as to take water from the sub-drain well, or they can take the condensing water through a special pipe from the Patapsco River.

The several sub-drains, laid in the side walls of the intercepting sewers, are brought together at a well underneath the small pump room. A gate is placed at the head of this well, so that it can be entirely shut off from the drains. The well is lighted from the pump room floor.

If the ground water is not used for condensing purposes, it can be pumped from this well into the storm drain now laid in Stockholm street.

The boiler house is so arranged that additional boilers can be set up and put into service at any time. A small car track is provided for bringing coal to the boilers and for carrying away ashes.

The coal house at the end of the boiler house is intended to be large enough for storing about 200 tons of coal. Teams can be driven up the inclined roadway and the coal dumped through manholes in the roof; or, a spur-track can be laid around the pumping station, and the coal delivered directly from the cars into the coal house through chutes placed in the windows.

The chimney is about 250 feet high and the interior diameter of its core is 11½ feet. It is so arranged that an economizer can be placed in the smoke flue, leading from the boilers to the chimney.

The station is equipped with an office for the chief engineer and has also a bathroom and a coat-room.

A traveling crane should be placed in the pump room for convenience in handling the machinery during erection and for making repairs at any time.

It should be stated that a sewage pumping station need not cause any nuisance in the neighborhood. The sewage is brought into the station under ground by the sewers, and the screens, pump wells and other receptacles are all under cover. The screenings are destroyed by burning, and the sewers, wells and chambers, as well as the buildings themselves, are thoroughly ventilated. Large sewage pumping stations exist within the cities of London and Berlin and give no offense whatever. Those in Boston are outside of the city, but there is no odor noticeable in their vicinity.

The sewage collected by the high level system at Eutaw and Franklin streets, eventually from 365,000 persons, has been estimated at 54,750,000 gallons in twenty-four hours, and the maximum rate of flow at 82,125,000 gallons per twenty-four hours. A small addition for ground water brings this rate to about 83,000,000 gallons.

The discharge mains, which carry the sewage to the filtration fields at Glen Burnie by gravity, will be two pipes 60 inches in diameter, with a maximum velocity of about 3.3 feet per second. As the total quantity of both sewage and ground water is estimated at 55,625,000 gallons in twenty-four hours, the mean average velocity will be slightly less than 3 feet per second.

The route selected for these gravity mains, starting at Franklin street, is through Eutaw, Henrietta, Charles, Moale and Byrd streets to near the Ferry Bridge, crossing the river nearly parallel with the bridge. The route then takes a straight course, almost due south, to a tunnel through the ridge, thence continues in the same direction to near Cabin Creek, where it turns slightly to the west, following nearly parallel with the Annapolis turnpike to Glen Burnie.

These two gravity mains have a hydraulic gradient of .00068, when flowing at a velocity of 3 feet per second, and .0008 when discharging the assumed maximum quantity of sewage and ground water.

As it will be several years before the amount of sewage from the high level system reaches the quantity that these two mains can carry, only one main should be laid at first, from Franklin to Ostend street, and two mains from there to the Glen Burnie filtration fields, ending one of them at about the center of the fields. The latter is to be temporarily used for the discharge of the sewage pumped from the low level system, and the former for discharging the high level sewage by gravity.

As the quantity of sewage increases, additional mains can be added from time to time. But they will have to be built to Elvaton, as the area at Glen Burnie cannot properly purify more sewage than can be delivered by the two mains laid at first.

To discharge the sewage from the low level system by pumping, when there are one million people in the city, requires three 60 inch mains laid to the Elvaton filtration fields.

These mains will have an hydraulic gradient of .0011, causing an average velocity of 3 feet per second, but at times of a maximum discharge the velocity will be about 3.8 feet per second. The route chosen for them, starting at the pumping station, is, to and along Hanover street to Cromwell, Marshall and Dorsey streets, thence to Ferry Point, and crossing the river parallel to the mains previously laid. As the hydraulic gradient has a higher elevation than the mains to Glen Burnie, this line can be farther east and go partly around the hill, which makes the necessary tunnel shorter.

Two tunnels are therefore required south of the Patapsco River. One containing the two mains which discharge at Glen Burnie is about 8,000 feet long, and of sufficient size to permit of access to them at any time. The other tunnel contains three mains discharging at Elvaton. It can be higher and therefore shorter than the other, and is but 3,400 feet long.

In crossing the river the discharge mains are estimated to be encased in concrete, as shown by a section on the accompanying plans, Plate I. A branch pipe and gate should be provided at or near the river, to allow the mains to discharge into it at any time, should an accident occur to them.

As the velocity in the gravity mains for the first few years will not reach the average, it will be necessary to flush them occasionally by accelerating the speed of the pumps and drawing the necessary sewage from the low level system, for which arrangements should be made. For flushing the upper portion of the gravity mains, north of the pumping station, a branch connects them with the main interceptor in Leadenhall street, so that its contents may at any time be discharged into the low level system with a highly increased velocity. If practicable, the grade should be such that these mains can be completely emptied.

Careful investigations should be made regarding the best material for the discharge mains to insure durability and economy. The estimates of cost have been made on the assumption that steel plates are used in the construction and that the pipes are made in the most approved manner, with butt joints and counter-sunk rivetheads. In calculating the size Kutter's formula was used, with coefficient of roughness $n = .015$.

Q

ELEMENTS OF DESIGN.

a. Velocity of Sewage.

The question of velocity is very important, because if it is too slight, sewage matter will not be carried off but will be deposited and if it is too great, a gradual destruction of the material of which the sewers are built will take place.

In order to make sewers self-cleansing as much as possible and to prevent deposit and foulness, the *least* velocity of the sewage should at no time fall below 20 inches per second. When sewers are first put into operation, comparatively few houses are connected with them, and therefore the quantity of sewage will be comparatively small. At such times, however, the velocity should be not less than 20 inches per second. This remark is of importance only with reference perhaps to the upper end of the proposed intercepting sewers and to the branch or lateral sewers in comparatively level territory. At the upper end of the interceptors the difficulty, if expected, may be somewhat overcome by adopting an egg-shape rather than a circular section, as mentioned below.

The hilly nature of most of the city will generally secure a good velocity in both main and branch sewers.

We have found it practicable to assume a mean velocity of four feet per second for nearly all of the high level and for the eastern and western low level interceptors. This velocity not only secures their comparative cleanness, but it also allows their size to be reduced. This improved condition, and the economy resulting from the reduction of size, we consider to balance the cost of an increased depth of excavation and of the additional height of pumping made necessary.

We found it impracticable to assume so good a velocity for the interceptors and mains collecting the sewage from Locust Point. It would have required either leaving out some important territory or an increased lift at the pumping station, which, under the conditions, was not economical. We therefore assumed a mean velocity of three feet per second.

Similar conditions made it advisable to reduce also to three feet per second the mean velocity in the eastern high level interceptor above Jones' Falls. And it was found economical to assume this same velocity for both the force mains extending from the pumping station, and for the discharge mains extending from the high level system to the filtration fields. A velocity of four feet per second in the latter case would necessitate a material reduction of the area wered by the high level system.

It is generally desirable to increase the velocity as the sewage proaches a pumping station or an outfall. Such gradual increase a good preventive of deposit, but it is not always practicable. the City of Baltimore, where the collecting interceptors must essarily have a light grade, the sewage in them will have less ocity than in the district mains and laterals which feed them. nsequently there will be more deposit in the interceptors than if the case were reversed. Ample arrangements for flushing them therefore become necessary.

The *greatest* velocity which should be allowed in a sewer was found, after much experience in England, to be about six feet per second; a greater velocity causes a gradual wear, even if the hardest materials are employed. This limit is confined to a continuous flow of sewage and not to the combined sewers where much greater mean velocities are occasionally permissible.

When the gradients of the streets are so steep that a sewer, laid parallel with the surface, would cause more than a six foot velocity, it is then proper that the grade of the sewer should be broken and vertical drops built to break also the velocity. Unless very hard and durable material can be employed in the construction of steep sewers, it may often be found advisable to reduce the continuous velocity of the sewage even to below six feet per second.

In fixing the gradients a careful distinction should be made between the slope of the bottom and the hydraulic slope, which is the free surface of the flowing water. While the bottom slope should be designed to give the least flow of sewage a proper velocity, the hydraulic slope, when the sewers have their maximum flow, should prevent a retardation due to junctions or to high water at the outfalls.

b. Shape and Size of Sewers.

The design of the sectional shape of a sewer should have for its object the concentration of the ordinary flow so as to increase the velocity and prevent the deposit of suspended matter. A flat bottom, for instance, allows the sewage to be spread out, the depth is reduced and consequently also the velocity.

The semi-circular form is the best section in this case for the flow of water. Where the flow varies considerably, as in the combined system of sewers, the egg-shape is a better form, because it gives an approximately semi-circular section for both small and large discharges. Where, however, the flow varies but slightly during the day, as in a separate system of sewers, it is preferable to adopt the semi-circular form and therefore circular sewers. In the few instances mentioned above, where a sewer is not expected to receive more than a small proportion of the computed quantity of sewage for a long time, it may be expedient to adopt an elliptical or egg form.

To give sewers their proper size is naturally of great importance.

If they are too small they will not carry the required quantity of water and will be liable to obstruction. If they are too large a useless expense will have been incurred and the flow will be more shallow and therefore more likely to facilitate deposits.

The smallest size that it is proper to give to your public sewers is a diameter of eight inches. A smaller size has occasionally been advocated, but experience has shown that no advantage is gained. It is true that a six inch pipe will remove the sewage from a large number of houses, but it is also true that, as experience has shown, these small pipes frequently become clogged up and cause trouble and expense in the removal of the obstructions. In England, experiments made by Latham show a remarkable difference in the number of stoppages occurring in a six inch and in a nine inch sewer, and there the latter size is employed as the minimum.

The least size to be given to house sewers is six inches, when they are made of clay pipe, and four inches when of iron pipe, which has fewer and more even joints. A six inch pipe is sufficient to carry off the sewage from a large dwelling house, and this size, if the public sewer is but eight inches, should therefore also be considered a maximum. When laying public sewers, it is proper to insert none but six inch branches for house connections, and in the case of specially large buildings, apartment houses or business blocks, to insert two of them.

The sizes should be computed on a basis of the maximum population which they are intended to serve. The quantity of sewage and of ground water allowed is given above for different existing conditions. For the maximum flow, the sewers should be computed to run not more than half full.

In making calculations for sizes, we have used Kutter's Formula, and assumed the value of n designating the degree of roughness, to be equal to .014. In constructing the sewers it will be found of great advantage to make the interior surface as smooth as possible, not only to reduce the coefficient of roughness, and therefore increase the capacity of the sewers, but also to prevent the adhesion of suspended matter which is liable to occur along the rough surface and by decomposition to cause foulness.

The sizes of the interceptors, as marked on the plan, are approximate and determined only for purposes of estimate. Before construction it will be necessary to carefully revise them. We give no sizes for the district sewers, as these can be easily determined when their exact locations are fixed.

c. Depth of Sewers.

The proper depth of sewers below the surface is governed by the usual depth of the cellars. Where possible, public sewers should be placed several feet below them so that the private sewers can freely discharge into them with a fall of at least ¼ inch per foot. In business districts the top of a public sewer is usually placed from 10 to 12 feet below the pavements, and in closely built up residence districts, nearly as deep. In the higher suburban districts, where cellar drainage is generally not demanded, the depth can be reduced, and is sometimes fixed at six feet. Where buildings are placed at a considerable distance back from the curb line, the depth of the public sewer must be sufficient to allow for the fall due to the increased length of the private sewers.

Interceptors should be laid deep enough to receive a free discharge from the district mains. But as they are generally laid across instead of in the valleys and depressions, their depth is sometimes considerable and at other times they are barely beneath the surface. The least depth in your city should allow for a covering of not less than eighteen inches—and better twenty-four inches—so as to prevent injury by frost or by traffic.

d. Alignment and Junctions.

The alignment of the branch and main district sewers is determined by the topography and by the local improvements. The mains will generally be placed along the lowest streets of the area. It may be found advantageous sometimes to place sewers in alleys instead of on the streets, because house connections may be made less expensive by carrying the sewer to the rear. But in view of the hilly nature of the territory it may seldom be possible to obviate the building of a sewer upon the street, and it may sometimes require also the placing of one in the adjoining alley, to receive the sewage from the buildings situated on the lower side of the street.

It is not only necessary to lay sewers with a perfect gradient, so as to obtain a regular velocity and prevent deposits, but it is also necessary that small sewers of 15 inches or less in diameter, should be laid perfectly straight in their direction, and that when a turn is necessary, it should be made entirely within a manhole. The advantage of this method of construction lies in the fact that every part of the sewer can then be inspected and, if necessary, cleaned from a manhole at any time.

The manholes should be conveniently located and provided with iron steps so that they can be easily descended. They should also be provided with locked covers, having openings for ventilation, and dirt pans under them to catch the dirt that falls through the openings. Such pans are of much more importance in a separate than in a combined system of sewers, and should, therefore, never be omitted. The dirt which they collect should be emptied regularly.

Where the gradients are sufficiently steep to allow of a drop at the manhole, it is best in that case even to lay pipes as large as 24 inches in diameter perfectly straight between the manholes. Larger sewers, when changing their directions, are curved with large radii. The impossibility of examining them directly from the manhole is not serious because they can be entered and thus inspected and cleaned.

The junctions of sewers form an important detail. When two or more streams are joined improperly, eddies occur and the suspended matter in the sewage deposits and accumulates. The streams should join each other in such a manner as not to meet undue retardation or resistance and so as to prevent eddies. The inverts should be of such relative heights that during the ordinary flow, the water surfaces of joining streams should have nearly the same height, so that one stream should not cause back water in the other. To overcome the loss of head in changing the direction, a corresponding fall should be given, particularly when the gradients are flat. The invert surfaces should continue until they naturally intersect and form between them what is called a *tongue.* The omission of the tongue always allows eddies to form and silt and filth to deposit. Where sewers cross drains in such a manner that one or the other needs siphoning, it is preferable to depress the sewer, and to preserve the grade of the drain for the better removal of the heavier silt carried along by it.

e. Ventilation.

The object of ventilating a sewer is two-fold:

First—The air, if confined within the sewer, is subject to compression and rarefaction by the rise and fall, and also by the change of temperature of the sewage. This variation of density in the sewer air often causes either a blowing out or a siphonage of the traps attached to the fixtures in the houses, and a consequent escape of foul air into the same. It is therefore necessary to maintain atmospheric pressure within the pipes, or, in other words, a free communication with the outer air.

Secondly—The sewage in its daily rise and fall, due to the different rates of water consumption during the day and night, coats the sides of the sewer with matter carried in suspension. By decomposition this coating may evolve offensive gases. Sewage that is not fresh, but has been temporarily held back by imperfect design or construction of the pipes and fixtures within the buildings, or by an imperfect manner of cleaning the same, not to mention a retention in cesspools, likewise becomes offensive. It is therefore desirable to dilute the sewer air sufficiently to make the gases contained therein unnoticeable and to neutralize their bad effect.

The problem of sewer ventilation therefore resolves itself into a provision for maintaining a direct communication between the air in the sewers and the atmosphere, and in causing the entrance of pure air, and its circulation through the sewers, to be as free as practicable.

The most perfect way of accomplishing the above conditions, is to ventilate the public sewers through the house drains and soil pipes of the buildings, to omit a main trap along the house sewer, which also acts as a retainer of foul matter, and to have perforations in the manhole covers of the public sewers. In this way an abundance of air can enter the system, not only from the outfall, but through the manhole covers, and circulate through the sewers and out through every private sewer to above the roofs of the buildings.

Such a method of ventilation, however, requires that the entire plumbing in the house is planned and constructed by responsible parties, so that the work will be first-class. It is also necessary to have the house pipes tested after the plumbing is finished, so as to be assured of tight joints.

This method has been tried in several cities in our country, and is the common one of the continent of Europe. But it is not the usual one in our country, for there is in the minds of many a fear that if the public sewer should be ventilated through the soil pipe of their house, some danger might arise, through a leak in their own pipes, of contracting a disease, the germs of which are supposed to come from the public sewer.

From experience in our country and in Europe, these fears are not well founded and there are no facts on record to justify them. On the other hand, the advantages of a thorough draft through the house pipes is considerable and keeps them much cleaner than where a trap is placed between the house and the sewer, thus disconnecting the two.

It has been said that air coming out of soil pipes below windows of adjoining houses might cause offense. But offense could also be caused if there were a main trap and the house pipes were foul, which they generally are not when used for ventilating the public sewers.

In those cities, however, where the municipal control of the house sewers cannot be secured it is deemed better to have such a trap and to confine the ventilation of the public sewers to whatever circulation is obtained from the openings in the manhole covers. It would be found in such a case, that near the upper end of your sewers the air would freely escape from these openings, and unless the sewers are kept scrupulously clean, its odor will be somewhat offensive, as observed in many cities. Then, when it becomes desirable to prevent this escape, there is no better practical way than by leading a special pipe from the manhole up to beyond the roof of an adjoining house, but with the practical difficulty of securing the proper rights.

A still less effective, though a somewhat palliative measure against the escape of the air at the highest manhole, is to hang a light rubber flap valve against the opening of the inlet pipe to the manholes below, which allows the sewage to flow by, but prevents much of the air from passing upwards into the pipe. By such means each section between two manholes is ventilated independently and the escaping air is likely to be less foul. If the sewers are kept properly cleaned, as they ought to be, the air should not be offensive or generally noticeable above the surface of the street.

It is often found that from a single new sewer offensive odors are at once emitted at the manholes, and this is also the case, even where an entire district is provided with new sewers. This objectionable feature may be due to the fact that at first but few house connections are made, and therefore an insufficient quantity of sewage is discharged to maintain a continuous flow, and thus deposits are allowed to form. The use of automatic flush tanks will, to some extent, obviate this trouble.

Escaping odor may also be due to the fact that the sewage comes from overflowing cesspools and is therefore in a foul condition. The trouble from this cause can, of course, not be prevented until there is legislation compelling the abandonment of such cesspools and the substitution of a modern system of plumbing and a direct connection with the sewer.

f. Inspection and Flushing.

A sewerage system may be well designed and well built, but it will not give perfect satisfaction unless it receives periodical inspection and cleansing. No matter how carefully grades and junctions are arranged, deposits, and even obstructions, are nevertheless liable to occur. In order to prevent objectionable consequences, it is necessary to do three things:

First—There should be a municipal control over the connections with the houses and the general arrangement of sewage receptacles on private premises, so as to prevent the introduction of matter for the removal of which sewers are not intended.

Secondly—There should be a periodical inspection of the public sewers to discover any slight accumulation of matter, which by increasing in bulk, might ultimately result in a stoppage.

Thirdly—There should be a periodical cleansing by flushing the entire system.

These demands are of far more practical importance where the separate system is adopted than where the sewers must be built materially larger.

The prevailing and unfortunate custom in this country to undervalue the importance of keeping sewers clean should not be followed in your city, where with a separate system, which will be more extensive than any other now in use, a comparative neglect in providing proper means for cleansing, and thereafter in frequently and properly using them, would be followed by far more extensive troubles than elsewhere.

As the smaller sewers are laid perfectly straight between points of access, the inspection is not difficult. A lamp with a concave reflecting mirror is held at one point, and an observer stands at the other, holding a plain mirror at an angle of 45 degrees, so that when looking into it he can see the entire stretch of pipe between himself and the lamp. When sewers are large enough to be entered, inspection is equally easy.

The upper ends of the sewers, receiving but a small amount of sewage, are most likely to have deposits, on steep as well as on light grades, and need more frequent flushing than when the ordinary flow is greater. Flush tanks are therefore necessary at all the heads. They are supplied with water from the city mains and may be automatic in their operation, discharging once or twice daily, or may be discharged by hand.

A flushing lower down the sewer is accomplished by inserting a plug at the manhole, which allows the sewage to accumulate in sufficient quantity behind it, and rush through the sewer when the plug is subsequently withdrawn. Special flush gates should be built into large sewers and used in a similar manner.

A very beneficial system of flushing, particularly the larger sewers, consists in the admission of a limited amount of roof water near the heads of the sewers, as already discussed under Section N. Separate System.

The interceptors having more deposit than the other sewers, on account of a reduced velocity, should be flushed by still other means. They should have large flushing tanks placed at their respective ends, each containing from 2,000 to 3,000 cubic feet of water, or even more, which can be discharged whenever demanded.

The western high level interceptor should have one built like a circular sewer of suitable diameter and length, at the point where it terminates at Gwynn's Run, and from which it should be fed. The eastern high level interceptor should have one near its head. It cannot readily be supplied either from Jenkins or Harford Run, and must, therefore, be filled from the public water supply. The western low level interceptor may have its flush tank fed by a special channel bringing water from either Gwynn's Run or Gwynn's Falls. The eastern low level interceptor may have its tank fed from the run discharging into the Gorsuch Creek, or, at a more distant future, from Herring Run. The interceptors from Locust Point, having less gradient than the others, should be provided with the largest flush tanks, and they will have to be filled from the public water supply.

There is another opportunity of flushing some of the mains and interceptors of the low level system of which advantage should be taken. Gates may be placed along the high level interceptors at points where its sewage can be temporarily passed down the main sewers of the low level system at will, and thence flow into the interceptor. A comparatively large and steady stream of sewage may thus be utilized with good effect and avoid the necessity of adding clean water to the sewage for this purpose, and thereby increasing the amount which must be lifted by the pumps and subsequently purified.

g. House Sewerage.

A few words should be added regarding what is considered a most important part of the system. The full benefit of a sewerage system can be experienced only when also that portion of it which extends into the houses and up to the various sewage receptacles, is properly designed and constructed. In fact, so far as the propagation of disease is concerned, the latter is more important than the public part of the system, because it brings any possible danger much nearer to the individual.

Usually the design and construction of the house sewerage works are left entirely in the hands of the property owner. We cannot too strongly urge that the custom prevailing almost universally in Europe, and already to some extent in this country, be adopted also in Baltimore, according to which the municipality has control of the general design and of the pipe arrangements within the buildings, and in some cases also of their construction. It must be admitted that the owners are usually obliged to rely upon an expert plumber or architect. But in many cases the cost of getting good advice cannot be paid, and among the poorer classes therefore defective plumbing is most often found.

To protect such citizens and their neighbors against the dangers arising from improperly arranged sewer pipes and fixtures within their houses, and also to guard the public sewers against misuse, it is now becoming customary to adopt and enforce so-called plumbing regulations and also to control the general design as well as the sewer connections. While assuring all reasonable liberty to the owner, he should be compelled to adhere to certain regulations, both for his own benefit, as well as for that of his neighbors.

B

STORM DRAINAGE SYSTEM.

It has already been stated that the rain-water must be carried off by a separate system of drains. You have already constructed many of such drains and they discharge into the several water-courses within the city limits and into the harbors.

Some data concerning the existing drains were furnished us, but the available information is scant. There is some uncertainty as to the actual boundaries of several of the drainage areas, as taken from the maps furnished to us. It is said that sometimes the actual areas are known to differ from those obtained from the contour survey, and that therefore artificial boundaries exist. Further, there are now relief drains in some instances which run from one area into another, and thus complicate the system; and there are instances where parallel drains exist within the same area. It is not possible to determine from the maps what proportion of the water is received by each of them. Conditions required a consideration from us that are liable to change from time to time and affect the location of drains.

In view of these uncertainties, it was found impracticable to design a general system so far as the actual alignment is concerned. But in our opinion it is sufficient for present purposes to discuss the questions in such a manner so as to establish the general principles that should be adopted, and according to which it will be a very simple matter for local engineers to determine the location and design of any particular drain at the time when this may be required.

The following, therefore, gives the principles upon which, in our opinion, the draining system should be based.

As the contents of the drains carrying only rain-water and subsoil water, are not offensive, because any sewage which now enters the same will be excluded, the outfalls can be placed at the most convenient points along the shore.

Inasmuch as drains are mostly of large size, their direction should be as short as possible to the outfall. They should also be placed as nearly as possible along the lowest territory of the area. It will be found economical to concentrate the water as soon as possible into large drains, instead of endeavoring to build several drains of a smaller size.

In view of the expense of the main drains, and from the fact that they are often not built until the territory has been laid out, it would be well to settle upon the most economical lines at an early day, in order to secure the necessary property thereon, and it will also in some cases be found economical and expedient to lay out a street along the lines found best for the drains.

Regarding the sizes, they should of course be sufficient to carry off the water from the heaviest storms, and therefore be proportioned for the run-off, which has already been discussed.

When building drains through lower and already well built-up districts, it is hardly necessary to say that they should be proportioned for the future condition of the entire drainage area, although the upper parts of it may now be sparsely populated.

Regarding the shape of the drains there is little to be said in addition to what has already been said regarding the shape of the sewers, excepting that in the absence of foul liquids, it is not as necessary to concentrate the flow as it is in the case of sewage. There being usually but little head available in the lower parts of the city, where we naturally find the largest drains, the sectional shape will of necessity be wide and shallow. If found practicable it is preferable, instead of having a perfectly level bottom, as in the present large drains, to have a slightly V-shaped bottom, formed either of timber or concrete, by which a more thorough removal of the deposit by the natural flow of the stream may be expected.

The gradients of the drains will in your city be partly very flat and partly quite heavy. The usual formulae will indicate what the least gradient should be for any particular drain, taking into consideration the fact that many storms will bring in silt, and if the velocity is insufficient, will deposit and tend to fill the drains. In their design, consideration should also be given to the hydraulic gradient of the water during the heaviest storms, which should in no case rise to such an elevation as to cause flooding. It is at times when the capacity of the drains is most severely taxed that the advantages of a proper design are most decidedly felt.

In some parts of the city the drains will naturally have very steep grades. In some instances it may be found advisable, as in the case of sewers, to insert drops along the lines of the drains, in order to break an excessive velocity which might tend to destroy them. While a continuous flow of six feet per second is deemed a maximum velocity, an occasional flow, such as during rainstorms, can safely be increased to twelve or even fifteen feet per second, when however, the drains must be built of great strength.

It would be well for the city to have authority to establish the grades of those streets upon which main drains will be required in the future, before the property is being improved by erecting buildings and by paving. The construction of drains is sometimes made quite difficult by the fact that the streets are not only improperly laid out, but also improperly graded to suit the future demands for draining the territory.

The admission of rain-water from the streets should be obtained through inlets placed more frequently than at present, so as to reduce their size and avoid the unsightly and dangerously large openings now existing along the streets. It will be evident, that the more frequently they are placed, the less water will accumulate at the foot of a hill, and therefore, the smaller the opening need be.

We are also of the opinion that the inlets should not be provided with catch-basins to retain the silt or whatever may be washed into them. The object of such basins is to intercept the heavy matter and periodically cart it away, instead of allowing it to reach the drains and there to deposit. Catch-basins, even after the sewage flow no longer exists in the gutters, are still apt to get foul because of the organic matter washed from the streets. Such foulness is less offensive in the drains than in the catch-basins, which are situated at the sidewalks, and where it is much more likely to be observed. Also, it is found impracticable to intercept all matter in the catch-basins which would deposit in the drains after they reach the flat grades in the lower part of your city. The cleaning of the drains would, therefore, be necessary in any event, and the additional amount of silt that would otherwise be intercepted by the catch-basins, will not cost much more to remove.

In the city of Paris, even though a combined system of sewers is used, it is not found objectionable to allow all the street dirt to enter the sewers and therefore the catch-basins at the inlets are omitted.

While we recommend that no catch-basins shall be used, we also recommend the disuse of traps, excepting in special cases, where it may be found desirable. Where one is required, it can be made in the form of a mechanical or swinging trap, rather than a water trap, which necessarily implies a catch-basin. A hanging trap, although not entirely excluding the air, is entirely sufficient, when applied to a drain from which the sewage is excluded, and where, in the worst cases, but a slight odor will exist in the drain that would not be noticed when a hanging trap is used.

The question of ventilation of drains receives a very simple solution by the omission of traps from the inlets, as there will be a continual circulation of air, which, if sewage is excluded, will not cause offense. The comparatively large size of the drains, and the consequent abundance of circulating air, can only in cases of gross carelessness, or under extraordinary conditions, permit of any objectionable odor. The first part of a rainstorm brings in the dirtiest water, which, during the latter part, is usually carried to the outfall. The use of traps prevents a proper circulation of air, and therefore a proper oxidation of whatever foul matter may have remained.

The sudden entrance of water from the rainstorms will necessarily compress the air in the drains, and force it out at points where the resistance is least. The escape of air at such times would, therefore, be far more objectionable than when the drains are continuously exposed to natural ventilation.

It is quite material that the bends or turns of drains and the junctions of two or more of them should be properly designed, so as to prevent any reduction in the velocity of the water during the greatest discharge. If there is an obstruction, caused by an improperly built junction, it will affect the discharging capacity by reducing it in the stretch above the obstruction. Therefore, to obtain the full benefit of the carrying capacity of the drain itself, the design should be carefully made with a view of not retarding the velocity of the water at any point.

In order to prepare for the proper location and design of drains when they may be required here and there, a map should be made showing the actual outlines of the drainage areas, the character of the territory as to its degree of perviousness, and the practical lines for main and branch drains, which are consistent with the existing drains, and with the engineering requirements as mentioned above, and also with other local requirements which are not at present apparent to us.

S

SUB-DRAINAGE SYSTEM.

The necessity for pumping and treating the sewage makes it, of course, economical to prevent from getting into the sewers any water that is not foul and does not require purification. It is, therefore, advisable to prevent sub-soil water, as much as possible, from finding its way into them. These should, therefore, be constructed as water-tight as practicable. But, inasmuch as a subdrainage of the soil is desired, and is in fact necessary in some parts of the city so as to prevent wet cellars, a proper provision should be made for it.

In the higher parts of the city, a collection of the sub-soil water will not be difficult. Where required, special drains can be laid with sufficient depth to accomplish this purpose and discharge into the rain-water drains at a sufficient height so that an annoyance by back water during heavy storms will not be felt.

In the low sections of the city, however, near the wharves, a different treatment is necessary. The sewers in that section of the city will be built below tide level, and low enough to collect the sub-soil water. Inasmuch as it would occupy space of the interceptor intended for sewage removal, and also require pumping and delivery at the filtration area, it is best not to use the sewerage system for its collection. A separate system of sub-soil drains can be readily laid in that part of the city to comply with the demands of cellar drainage. The water would undoubtedly have to be collected below high water level, and it would, therefore, be necessary to pump it. Unless other and special provisions can be made, it will be found best to lay these sub-drains when building the low level interceptor, one on each side, and deliver the sub-soil water also at the pumping station, where special pumps can lift it and discharge it into the harbor.

The additional expense of thus treating the sub-soil question in the low parts of the city will, therefore, not be very great. The plan of the pumping station includes a provision for pumping this water from the low territory between Washington street in the east, to Gwynn's Falls in the west.

The allowance made for the quantity of sub-soil water which may enter these special drains of the low territory, as discussed above in Section "E," is 1,200 gallons per acre per day. The sizes of the drains, where built along the interceptors, range from 8 inches to 24 inches diameter on each side, and the branches should gradually diminish to 3 inches diameter.

The allowance which it was thought proper to make for the leakage of sub-soil water into the sewerage system itself, and which would therefore reach the interceptors, is fixed at 160 gallons per acre per day.

T

ESTIMATES OF COST OF THE SEWERAGE SYSTEM.

No soundings of the ground nor special surveys have been made for the purpose of estimating the cost of the works that have received consideration. The character of the foundations has been determined only from general information. We have endeavored to make the estimate of cost on a safe basis where uncertainties exist. The unit prices are ample and some of them may perhaps be reduced.

The cost of the local or district sewers, collecting the sewage from buildings, is the same for any system of disposal. A detailed design of the local system was neither contemplated nor practicable with the information on hand. As it is usual for the adjoining properties to be assessed for the cost of local sewers, we further considered it to be of no value in arriving at the expense of interception and disposal, after the sewage had been collected, which expense alone falls upon the city at large.

As the important questions before us related to the best manner of interception and disposal, we give the cost of the local or district sewers per square mile of territory, and we selected two conditions, namely, the densely built-up parts and the suburban parts of the city. The cost is based in both cases upon the average length of streets and alleys within a square mile and included both mains and laterals. The excavation is supposed to be in earth and all works done in a thorough manner. House pipes are not included, but merely a Y branch in the sewer at which they connect. All streets are supposed to have been paved.

This information will be sufficiently close to gain a fair idea of the expense in any district which it is desired to sewer.

We have assumed that in the business districts there will be about thirty miles of sewers, and in the suburban districts about ten miles of sewers in a square mile. The cost per square mile in the former would be about $480,000, and in the latter about $110,000.

The estimates of cost for the interception and disposal of the sewage has been made, both for immediate needs, and for such a time when one million persons contribute to it. The former represents the amount of money required for the different projects at the outset; the latter, for the purpose of comparing the eventual cost of the several projects which have been examined.

Statement A gives the expense of constructing the works, Statement B, the annual expense of operating them, the interest, renewals, etc. The latter statement allows a fair comparison to be made between the economy of the several projects.

Some parts of the work, when once built, will answer for all time, so far as their capacity is concerned. The interceptors, for instance, are expected always to serve the territory for which they are intended. The outfall sewer of the dilution and precipitation projects would at once answer for discharging the sewage from one million people. Some parts will have to be added to later, such as the pumping machinery. Still other parts may have to be abandoned later, should, for instance, a temporary chemical disposal plant be placed on the shore of the Patapsco River, near the line of the discharge mains to Glen Burnie.

A summary of the estimates of cost is inserted herewith. The detailed estimates of cost will be found in the Appendix. It will be noticed that the dilution project is the least expensive one, both for immediate and future needs. The filtration project is the most expensive one in both cases.

Were the basis of cost to be the only criterion upon which to reach a decision, the project of disposing of the sewage by dilution in Chesapeake Bay would have to be preferred.

SUMMARY OF ESTIMATES OF COST.

Project.	A Construction, Total Cost.	B Maintenance, Interest and Renewals per annum.
1. *Dilution* :		
a. For immediate needs	$3,880,167	$213,700
b. For one million persons	5,129,167	290,460
2. *Precipitation* :		
a. For immediate needs	$2,962,000	$284,400
b. For one million persons	5,503,000	665,000
3. *Filtration* :		
For immediate needs with		
a. Temporary precipitation	$3,019,012	$301,355
b. Filtration at Glen Burnie	5,741,007	402,752
c. For one million persons	12,171,803	913,044

U

RECOMMENDATIONS.

The several ways in which the sewage question, as related to the City of Baltimore, can be solved, have been discussed above. The conditions which govern the solution are clearly set forth. Each one of the projects which satisfies them, has been worked out so as to give results as satisfactory as practicable.

The collection of the sewage from private premises, we find to be preferably accomplished by means of a separate system of sewers into which no street water is to be admitted.

The collection and disposal of the rain-water we find should be accomplished substantially in the same manner in which it is done at present, with a modification of some details.

The final disposal of the sewage required the consideration of three methods, which are all applicable and according to any of which the sewage can be disposed of without offense. Some of them are better than others.

We unhesitatingly state that, irrespective of cost, the purification of the sewage by filtration through sand is the best method, because it effectually destroys all decomposable matter within a short time after the sewage is delivered upon the fields. It enables the sewage to increase the fertility of land for agricultural purposes and to guard against crop failures from droughts. It causes no objectionable results, either on the fields themselves, or after the purified sewage drains away from them, if the works are properly laid out and fairly well managed.

The operation of filtration fields requires labor of no great skill, and good results can be secured whether crops are raised or not.

Both the precipitation and dilution methods are less satisfactory, because in the former case greater attention must be given to the treatment, if a nuisance is to be prevented, and in the latter case there is a danger to some of the oyster beds, and a pollution of the Bay for a considerable distance from the outlet.

As on the Berlin sewage farms are located public institutions, including homes for convalescents and paupers, who are employed upon the fields, and as the Rhode Island State Institutions in Cranston use their inmates to care for the sewage farms connected therewith, so could the filtration territory of Baltimore contain similar institutions, upon which convict and pauper labor might be utilized in a very satisfactory way to materially reduce the cost of distributing the sewage and for attending the farms.

We believe that it is the desire of your citizens to adopt the best method of disposing of the sewage and that they are willing to pay a larger sum for it than for others which are less good. The experience in other cities has generally shown that both precipitation and dilution methods were on the whole less satisfactory than the filtration method, and they are now recommended only for such cities where filtration is impracticable.

As we fully believe that your intelligent citizens will not regret a greater outlay for a greater benefit, we do not hesitate to recommend to you the filtration system.

In closing, we desire to convey our thanks for many courtesies received while studying the problem, from yourselves, from Mr. Kenneth Allen, C. E., principal assistant, and Mr. Rector, secretary, and from others who have contributed information regarding the subject.

Respectfully presented,

RUDOLPH HERING,
SAMUEL M. GRAY.

V

APPENDIX I.

GEOLOGY OF BALTIMORE AND THE REGION ADJACENT TO THE LOWER PATAPSCO RIVER.

By WM. BULLOCK CLARK, State Geologist.

The State of Maryland is divided into three clearly defined regions, known respectively as the Coastal Plain, the Piedmont Plateau and the Appalachian Region, each of which contains definite physiographic and geologic features which characterize it. The City of Baltimore is situated near the boundary line of the first two districts, its higher portions resting upon the rocks of the Piedmont Plateau, while its lower portions occupy the landward border of the Coastal Plain.

THE PIEDMONT PLATEAU.

The Piedmont Plateau, which lies along the eastern flank of the Appalachian Region and occupies the country lying between Baltimore and the Frederick Valley, is the southward extension of a continent of early geological time, the main body of which was largely within the limits of the British possessions of the present day. Toward the south it existed as a narrow belt that continued almost to the Gulf border. The rocks composing it are more or less crystalline, while the structure throughout is highly complicated. Within the limits of Maryland the rocks of the Piedmont Plateau are divisible into two distinct classes. In the eastern portion of the region, in the vicinity of the City of Baltimore, they are completely crystalline, physical and chemical changes of such moment having taken place in both the ancient sediments and the eruptive rocks that penetrate them as to often obscure their original characters. In the western portion, on the other hand, the rocks are semi-crystalline, and while they have been subjected to a certain amount of metamorphism and alteration, they still plainly show that they were once sediments of an ordinary type.

It is upon the more highly crystalline rocks of the Piedmont Plateau that the City of Baltimore is situated. These various rock masses may be divided into six distinct types, three of which are of undoubtedly eruptive origin (gabbro, peridotite or pyroxenite, and granite), while the other three (gneiss, marble and quartz-schist), although at present exhibiting no certain traces of clastic structure, were probably sedimentary. Through these latter rocks the eruptives penetrated.

The gneiss is the prevailing rock of this area. It extends as a band from the northeast to the southwest, constantly narrowing southward, and shows great complexity of structure. The gneiss is sometimes quite constant in character for considerable distances, but more usually it consists of a succession of differently constituted layers. It may have had its origin in the impure sand deposits of early geological time.

The marbles are found intercolated in the gneiss complex, occurring as irregular and disconnected masses that show at a glance how intricate the stratigraphy really is. Although found to the north of Baltimore and at no place within the city limits, they form part of the same rock series and cannot be ignored in a discussion of it. They are much more coarsely and perfectly crystalline than the marbles and limestones of the more western portion of the State, and have lost all evidence of an original clastic structure. On account of their greater solubility they have been easily removed and now form depressions as the Green Spring, Dulaney and other valleys which are sharply bounded by the surrounding ridges of gneiss. As in the case of the gneiss, it is highly probable they were originally sedimentary accumulations rich in carbonate of lime.

The least important of the rocks of probable sedimentary origin in the Baltimore region, is the peculiar quartz-schist composed chiefly of quartz and divided into beds of various thicknesses by parallel layers of muscovite. The quartz grains are of different sizes, but are so completely re-crystallized that they form an interlocking mosaic. The quartz-schist never attains any great thickness. Whatever the origin of the quartz-schist may have been, it is closely allied to the gneiss into which it grades by imperceptible transitions. It is, however, always sharply defined against the limestones. It is not improbable that this rock represents facies of the gneiss produced by some dynamic agency.

The three types of eruptives have all broken through and have more or less modified the rocks just described, and are hence younger in age. The oldest, as well as the most extensive of the three eruptive rocks which so abundantly intrude the gneiss complex, is the gabbro. Its black color has given to it locally the name of "nigger-head rock." The action of pressure which has caused the re-crystallization of the gneiss and marble is also very marked in the gabbro. It has caused its iron magnesian constituent pyroxene, to change to another green mineral called hornblende. This has in some cases left the rock as massive as before, and in other cases it has rendered it schistose. This resulting rock is called gabbro-diorite.

The next eruptive rocks in point of age are the basic-magnesia silicates, peridotite and pyroxenite and their alteration products serpentine and steatite. These rocks are intimately associated with the gabbros. They do not occur in as large masses as the other eruptive rocks, but occupy numerous smaller areas.

The youngest intrusive rocks are the granites. They also form numerous detached masses. The granites are so like the surrounding gneiss in chemical, as well as mineralogical, composition that when they have been greatly foliated through dynamic action it becomes a matter of no small difficulty to distinguish them. The gneisses of the Baltimore region are penetrated with a great abundance of dykes, veins and "eyes" of the coarse-grained granite known as pegmatite. The other crystalline rocks of the region, although to a less extent, contain the same material.

It will thus be seen that the ancient rocks which form the foundation upon which the City of Baltimore is situated exhibit a great variety of types which show highly complicated structures. They were very fully studied by the late Prof. Geo. H. Williams, and the above statements are very largely adapted from his writings.

THE COASTAL PLAIN.

The Piedmont Plateau is overlain upon its eastern margin by a series of geological formations of much more recent date, the material out of which they are formed having been for the most part derived from the more ancient rocks to the westward. These materials were carried down by the streams from the old continent and distributed by currents along the margin of the continent, at the time when the old shore-line was found in the vicinity of the City of Baltimore. These later sediments form a series of thin beds which are inclined slightly to the eastward, so that successively later formations are found in passing from the interior toward the coast. Although deposition undoubtedly went on throughout these later periods along the margin of the Piedmont Plateau, oscillations of the sea-floor were constantly going on, so that the formations along their landward margins were constantly raised above the level of the water and subjected to eroding influences. As a result, these deposits, in the vicinity of the Piedmont Plateau, present much complexity. Furthermore, the denuding effects of more recent time have left numerous remnants of them as detached masses upon the old crystalline rocks.

The later formations are composed of a succession of sands, clays, and marls that carry with them the remains of the animal and plant life that were entombed at the time they were deposited. The evidence presented by the succession of organic forms, together with the varying physical conditions of deposition, afford criteria upon which a satisfactory classification of the formations may be made.

THE CRETACEOUS (POTOMAC).

The oldest of the Coastal Plain formations is of lower Cretaceous age, and is known as the Potomac formation. It directly overlies the crystalline rocks of the Piedmont Plateau and is to a considerable extent formed of debris from them. The deposits consist chiefly of sands and clays with gravels at certain points where the shore accumulations are still preserved. Throughout the lower members there is a constant alternation of sandy and clayey layers which also show a horizontal gradation into one another. The sandy layers are often much limited in extent, being commonly found as lenticular masses, which rapidly diminish in thickness from their centres. Highly colored and variegated clays are found in the upper portion of the lower Potomac, and have yielded large amounts of nodular carbonate of iron. The upper Potomac is composed of more persistent beds of clay and sand, the prevailing deposit being a moderately coarse white sand that at times exceeds one hundred feet in thickness.

The Potomac formation constitutes the main portion of the long necks which extend eastwardly from Baltimore, burying from view the rocks of the Piedmont Plateau and in turn underlying the more superficial deposits of recent geological date. The ancient crystalline floor upon which these deposits rest reaches a constantly deeper level in passing from its eastern edge beneath the Coastal Plain. Although frequently out-cropping in the centre of the city, and in the regions to the north and south of the same, these old rocks are found several hundred feet below the surface at the eastern extension of all the necks adjacent to the Patapsco River. The Back River and Patapsco River necks differ very materially in their geological structure from those to the south of the Patapsco in that the upper sandy members of the upper Potomac formation are entirely wanting from the former, while they occur in their full and normal development in the area of Stony and Rock Creeks in the Magothy peninsula, and throughout the region to the south of it.

The later formations of upper Cretaceous and Tertiary age, succeeding the Potomac formation in the eastern section of the State, and with here and there scattered remnants reaching almost to the borders of the Piedmont Plateau, are wanting in the region now under discussion. That most, if not all, of them formerly reached well within the limits of the city there can be but little question, but they have long since been removed by the processes of erosion. The deposits of the latest geological epoch are, however, fully represented and will be further described.

THE PLEISTOCENE (COLUMBIA).

Superficially overlying the other formations of the Coastal Plain are deposits of Pleistocene age which have been described under the name of the Columbia formation. They consist of gravels, sands and clays. They nowhere attain any great thickness, but give evidence of rapid accumulation in a geological epoch of short duration as compared with the Cretaceous and Tertiary periods previously mentioned. The deposits give evidence of two periods of submergence, during which the deep valleys, which had been carved out in late Tertiary time, were to a considerable extent blocked with debris, which has, up to the present, never been wholly removed. The earliest of these submergences reached well within the present limits of the city, admitting of the deposition of considerable deposits of gravel and sand over the uneven sea floor composed both of crystalline rock and Potomac strata. After an interim of brief elevation came a second submergence, of less extent, which covered the lower elevations within and to the east of the city, the sands and loams which were deposited forming a superficial coating of the country. The Columbia deposits, both of earlier and later date, have already been removed by natural processes from considerable sections of the country, both within and to the east of the city, laying bare, as in the vicinity of Stony and Rock Creeks, the great deposits of sand of the upper Potomac.

This brief statement of the geology of the Baltimore area would be incomplete without some mention of the history of the Patapsco River and its branches. Although that portion of the river system which crosses the crystalline rocks of the Piedmont Plateau may have existed prior to the submergence which brought about the deposition of the Potomac formation, yet its eastward extension, across the deposits of the Coastal Plain, is of far more recent origin. As was mentioned above, the carving out of the present valleys was accomplished by the streams at or near the close of the Tertiary. At that time the waters of the Susquehanna passed through the valley of the present Chesapeake Bay to and beyond the Capes, while the Patapsco River flowed in a deep valley to the main stream. Since that time various oscillations, recorded in the deposits of the Columbia formation, took place, finally leaving the Chesapeake Bay and the lower portion of the Patapsco as submerged valleys of the ancient rivers. As in the case of many of the other streams of the Coastal Plain, they become far less extensive bodies of water, and even insignificant streams, after the head of tide has been reached. It is also probable that along the line (so-called "Fall line") separating the Coastal Plain from the Piedmont Plateau a further depression took place in late geological time to more fully accentuate the difference.

From this brief summary it will be seen that the City of Baltimore and its vicinity comprises geological formations of widely different age and character, and has passed through a long cycle of varying physiographic and geologic changes.

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APPENDIX II.

List of rainfalls occurring during the past 25 years or more in Baltimore and other places in Maryland, in Washington, D. C., and in Philadelphia, Pa., having a duration of 10 minutes or more, and a rate equal to or greater than one inch per hour. Some storms of long duration, but of less rate than one inch per hour, have also been added. The storms marked by a star (*) were recorded by automatic gauges, and in such cases storms of less rate than two inches per hour have been excluded.

Place.	State.	Date.	Amount in inches.	Duration		Rate in inches per hour.
				H.	M.	
*Washington,	D. C.	June 30, 1895	1.06	0	10	6.36
Philadelphia,	Pa.	July 23, 1887	0.92	0	13	4.25
Washington,	D. C.	July 26, 1886	0.70	0	10	4.20
*Philadelphia,	Pa.	April 16, 1891	0.67	0	10	4.02
Philadelphia,	Pa.	August 31, 1888	0.80	0	12	4.00
Chestertown,	Md.	August 15, 1894	1.85	0	30	3.70
Washington,	D. C.	August 10, 1878	0.80	0	13	3.69
Philadelphia,	Pa.	August 8, 1888	0.90	0	15	3.60
*Washington,	D. C.	August 6, 1889	0.60	0	10	3.60
Washington,	D. C.	Sept. 16, 1888	1.19	0	20	3.57
Washington,	D. C.	Sept. 3, 1882	1.03	0	18	3.43
*Washington,	D. C.	July 2, 1890	0.57	0	10	3.42
Washington,	D. C.	Sept. 12, 1887	0.62	0	11	3.38
Washington,	D. C.	July 1, 1884	0.56	0	10	3.36
Washington,	D. C.	July 28, 1877	0.78	0	14	3.34
*Washington,	D. C.	August 1, 1890	0.55	0	10	3.30
*Baltimore,	Md.	July 16, 1895	0.55	0	10	3.30
Washington,	D. C.	August 6, 1889	0.55	0	10	3.30
Washington,	D. C.	April 28, 1878	0.82	0	15	3.28
*Philadelphia,	Pa.	August 21, 1890	0.53	0	10	3.18
*Washington,	D. C.	July 14, 1892	0.53	0	10	3.18
*Washington,	D. C.	June 21, 1891	0.52	0	10	3.12
Washington,	D. C.	July 29, 1877	1.44	0	28	3.09
Philadelphia,	Pa.	May 20, 1889	1.00	0	20	3.00
Philadelphia,	Pa.	August 4, 1889	1.00	0	20	3.00
Washington,	D. C.	June 7, 1881	0.60	0	12	3.00
*Philadelphia,	Pa.	April 16, 1891	0.50	0	10	3.00
*Washington,	D. C.	July 15, 1891	0.50	0	10	3.00
*Philadelphia,	Pa.	August 28, 1891	0.50	0	10	3.00
Washington,	D. C.	August 25, 1885	0.50	0	10	3.00
Washington,	D. C.	August 9, 1889	0.50	0	10	3.00
Washington,	D. C.	June 10, 1876	1.98	0	40	2.97
Philadelphia,	Pa.	Sept. 21, 1882	1.20	0	25	2.88
Washington,	D. C.	July 15, 1886	0.72	0	15	2.88
Washington,	D. C.	August 6, 1878	1.00	0	21	2.86
Washington,	D. C.	July 9, 1888	0.99	0	21	2.83
*Baltimore,	Md.	Sept. 8, 1894	0.47	0	10	2.82
Washington,	D. C.	May 27, 1882	0.70	0	15	2.80
Philadelphia,	Pa.	Feb. 18, 1887	0.51	0	11	2.76
*Baltimore,	Md.	August 31, 1895	0.46	0	10	2.76

Place.	State.	Date.	Amount in inches.	Duration H.	Duration M.	Rate in inches per hour.
Washington,	D. C.	August 5, 1878	2.08	0	46	2.71
*Washington,	D. C.	July 1, 1889	0.45	0	10	2.70
*Washington,	D. C.	June 22, 1890	0.45	0	10	2.70
*Washington,	D. C.	Sept. 11, 1890	0.45	0	10	2.70
*Washington,	D. C.	October 19, 1891	0.45	0	10	2.70
*Baltimore,	Md.	May 23, 1894	0.45	0	10	2.70
*Philadelphia,	Pa.	May 28, 1894	0.45	0	10	2.70
*Philadelphia,	Pa.	August 2, 1894	0.45	0	10	2.70
Washington,	D. C.	June 7, 1881	1.61	0	36	2.67
Washington,	D. C.	June 3, 1883	0.66	0	15	2.64
Washington,	D. C.	July 17, 1883	0.79	0	18	2.63
Washington,	D. C.	July 1, 1889	0.65	0	15	2.60
*Philadelphia,	Pa.	Sept. 14, 1892	0.43	0	10	2.58
Philadelphia,	Pa.	July 23, 1887	1.86	0	44	2.54
Philadelphia,	Pa.	July 6, 1884	0.50	0	12	2.52
Washington,	D. C.	October 4, 1877	1.08	0	26	2.49
Washington,	D. C.	July 18, 1871	0.83	0	20	2.49
*Washington,	D. C.	June 27, 1892	0.40	0	10	2.40
*Baltimore,	Md.	August 29, 1893	0.40	0	10	2.40
*Baltimore,	Md.	June 12, 1894	0.40	0	10	2.40
Philadelphia,	Pa.	Nov. 23, 1884	0.40	0	10	2.40
Pocomoke City,	Md.	April 27, 1895	1.59	0	40	2.38
Washington,	D. C.	August 11, 1887	0.71	0	18	2.37
Washington,	D. C.	Sept. 25, 1872	1.18	0	30	2.36
Washington,	D. C.	August 21, 1888	0.59	0	15	2.36
*Philadelphia,	Pa.	July 3, 1892	0.39	0	10	2.34
Woodstock Coll.,	Md.	May 19, 1878	2.00	0	52	2.31
Washington,	D. C.	June 23, 1888	0.50	0	13	2.31
Washington,	D. C.	June 3, 1883	0.46	0	12	2.30
Washington,	D. C.	July 3, 1871	1.13	0	30	2.26
Philadelphia,	Pa.	July 23, 1887	2.25	1	00	2.25
Barren Crk. Spgs.,	Md.	May 20, 1889	2.25	1	00	2.25
Washington,	D. C.	July 29, 1878	0.95	0	26	2.19
Baltimore,	Md.	July 11, 1884	3.75	1	43	2.18
*Washington,	D. C.	April 11, 1891	0.36	0	10	2.16
*Baltimore,	Md.	July 6, 1894	0.36	0	10	2.16
*Philadelphia,	Pa.	April 9, 1895	0.36	0	10	2.16
Philadelphia,	Pa.	June 12, 1895	0.36	0	10	2.16
Philadelphia,	Pa.	July 26, 1887	1.16	0	33	2.11
Wood Lawn,	Md.	August 11, 1875	2.10	1	00	2.10
*Washington,	D. C.	June 10, 1889	0.35	0	10	2.10
*Washington,	D. C.	May 30, 1890	0.35	0	10	2.10
*Washington,	D. C.	Nov. 23, 1891	0.35	0	10	2.10
*Philadelphia,	Pa.	Sept. 8, 1894	0.35	0	10	2.10
Washington,	D. C.	June 27, 1885	0.35	0	10	2.10
Washington,	D. C.	June 14, 1888	0.38	0	11	2.07
Washington,	D. C.	July 30, 1878	1.10	0	32	2.06

Place.	State.	Date.	Amount in inches.	Duration H.	Duration M.	Rate in inches per hour.
Philadelphia,	Pa.	Sept. 16-17, 1888	0.55	0	16	2.06
*Philadelphia,	Pa.	August 25, 1892	0.34	0	10	2.04
*Philadelphia,	Pa.	Sept. 14, 1892	0.34	0	10	2.04
Philadelphia,	Pa.	August 23, 1888	0.34	0	10	2.04
Fort McHenry,	Md.	July 11, 1884	3.54	1	45	2.02
Sandy Springs,	Md.	July 5, 1880	5.00	2	30	2.00
Cambridge,	Md.	July 31, 1893	4.00	2	00	2.00
Sandy Springs,	Md.	July 19, 1878	2.00	1	00	2.00
Washington,	D. C.	August 11, 1873	1.00	0	30	2.00
Philadelphia,	Pa.	August 3, 1885	2.80	1	25	1.98
*Philadelphia,	Pa.	Sept. 5, 1891	0.33	0	10	1.98
*Philadelphia,	Pa.	June 21, 1892	0.33	0	10	1.98
Washington,	D. C.	July 21, 1886	0.46	0	14	1.97
Philadelphia,	Pa.	August 31, 1889	1.17	0	36	1.95
Washington,	D. C.	August 18, 1875	0.78	0	24	1.95
*Washington,	D. C.	August 24, 1891	0.32	0	10	1.92
*Philadelphia,	Pa.	Sept. 15, 1893	0.32	0	10	1.92
Washington,	D. C.	July 29, 1877	2.33	1	18	1.78
Baltimore,	Md.	August 21, 1890	1.96	1	10	1.68
Emory Grove,	Md.	May 15, 1879	5.00	3	00	1.67
Easton,	Md.	July 21, 1894	3.04	2	00	1.52
Washington,	D. C.	July 29, 1865	4.92	3	15	1.51
Philadelphia,	Pa.	July 6, 1884	1.50	1	00	1.50
Baltimore,	Md.	August 22, 1887	1.74	1	10	1.49
Washington,	D. C.	October 4, 1877	1.49	1	00	1.49
Philadelphia,	Pa.	August 1, 1878	1.43	1	00	1.43
Washington,	D. C.	July 26, 1886	2.23	1	35	1.41
Woodstock Coll.,	Md.	August 21, 1890	2.80	2	00	1.40
Washington,	D. C.	October 23, 1875	1.40	1	00	1.40
Washington,	D. C.	October 23, 1876	1.40	1	00	1.40
Washington,	D. C.	July 26, 1879	1.73	1	15	1.38
Washington,	D. C.	October 26, 1879	1.73	1	15	1.38
Emory Grove,	Md.	October 22, 1878	4.00	3	00	1.33
Easton,	Md.	Sept. 19, 1895	1.33	1	00	1.33
Baltimore,	Md.	August 10, 1873	1.30	1	00	1.30
Philadelphia,	Pa.	August 9, 1874	1.30	1	00	1.30
Washington,	D. C.	August 29, 1874	1.30	1	00	1.30
Washington,	D. C.	August 29, 1875	1.30	1	00	1.30
Washington,	D. C.	July 26, 1886	3.14	2	27	1.28
Washington,	D. C.	June 30, 1895	1.28	1	00	1.28
Philadelphia,	Pa.	July 12, 1878	1.27	1	00	1.27
Solomon's,	Md.	August 20, 1893	1.47	1	10	1.26
Philadelphia,	Pa.	July 10, 1876	1.25	1	00	1.25
Oldtown,	Md.	August 6, 1895	1.25	1	00	1.25
Baltimore,	Md.	June 27, 1892	1.23	1	00	1.23
Washington,	D. C.	October 29, 1885	1.20	1	00	1.20
Baltimore,	Md.	May 20, 1889	1.20	1	00	1.20

Place.	State.	Date.	Amount in inches.	Duration H.	M.	Rate in inches per hour.
Taneytown,	Md.	July 1, 1892	1.20	1	00	1.20
Woodstock Col.,	Md.	August 22, 1887	1.56	1	21	1.16
Philadelphia,	Pa.	August 21, 1890	1.16	1	00	1.16
Jewell,	Md.	Sept. 16, 1888	3.75	3	15	1.15
Washington,	D. C.	Sept. 25, 1872	2.07	1	48	1.15
Baltimore,	Md.	June 4, 1891	1.15	1	00	1.15
Washington,	D. C.	June 21, 1877	1.64	1	26	1.14
Fallston,	Md.	August 12, 1893	2.85	2	31	1.13
Baltimore,	Md.	August 12, 1875	1.41	1	15	1.13
Baltimore,	Md.	July 31, 1884	1.40	1	15	1.12
Baltimore,	Md.	August 5, 1888	1.12	1	00	1.12
Fort McHenry,	Md.	May 28, 1882	2.50	2	15	1.11
West Wash.,	D. C.	Dec. 24, 1891	1.09	1	00	1.09
Gambrill's,	Md.	August 23, 1889	2.13	2	00	1.07
Washington,	D. C.	October 23, 1876	1.89	1	47	1.06
Washington,	D. C.	August 6, 1889	1.05	1	00	1.05
Baltimore,	Md.	July 5, 1895	1.05	1	00	1.05
Washington,	D. C.	October 4, 1877	2.05	2	00	1.03
Baltimore,	Md.	August 8, 1888	1.03	1	00	1.03
Frederick,	Md.	Sept. 13-14, 1892	4.07	4	00	1.02
Wood Lawn,	Md.	August 18, 1875	2.00	2	00	1.00
Washington,	D. C.	Nov. 24, 1884	1.00	1	00	1.00
Barren Crk. Spgs.,	Md.	May 20, 1889	1.00	1	00	1.00
Sunnyside,	Md.	July 27, 1894	1.00	1	00	1.00
Washington,	D. C.	July 1, 1884	1.95	2	03	0.95
Washington,	D. C.	July 24, 1868	2.30	2	30	0.92
Washington,	D. C.	October 4, 1877	2.49	3	00	0.83
Washington,	D. C.	July 27, 1873	2.00	2	00	0.80
Washington,	D. C.	August 29, 1875	2.30	3	25	0.67
Washington,	D. C.	August 1, 1875	2.13	3	24	0.62

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APPENDIX III.

CAPACITY OF A FEW DRAINS AND THE PROBABLE FUTURE RUN-OFF.

NOTE.—The capacities of some of the present drains, and the probable run-off from the ritories respectively drained by them, have been computed as closely as possible, and the ults are shown in the following table:

Location.	Size.	Area Sq. Feet.	Mean Radius.	Hydraulic Slope.	Present capacity in cu.ft. per sec., running full.	Number of acres drained.	Average Slope of Territory per 1000.	Character of Territory.	Eventual Run-off in cu. ft. per sec.
Penn Street and Lombard,	16′ x 8′	104.73	2.52	0.95%	1876	320	23	Well built up, Business,	519 658
Pulaski Street and Franklin,	11′ diam.	95.03	2.75	0.8%	1646	500	37	Sparsely built up, Well built up,	589 824
Calhoun Street and Mosher,	4′ 6″ diam.	15.90	1.125	2.0%	240	121	23	Sparsely built up, Well built up,	173 240
Lovegrove Alley and 20th Street,	6½′ x 6′	28.27	1.57	1.36%	469	212	25	Well built up,	380
Cor. Carey and Herkimer,	17′ x10′	121.42	2.92	0.65%	1979	593	25	Well built up,	865
Cor. Bush and Columbia,	19′ x10′	135.39	3.00	0.50%	1973	847	25	Well built up,	1150
Broadway; cor. Lombard & Ann	3′ 0″	7.068	0.75	1.58%	70	68	24	Well built up,	113
Cor. Ann & Gough,	3′ 3″	8.295	0.81	1.8%	93	83	25	Well built up,	133
Cor. Eastern Ave.,	4′ 0″	12.566	1.00	1.0%	123	131	23	Well built up,	255

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APPENDIX IV.

ESTIMATES OF COST.

A.—Summaries for Construction.

1. *Dilution Project:*

a. All interceptors, pumping station, force main and the outfall sewer are sufficient for the sewage from one million persons; the outlet pipe and pumping machinery are for about one-third of the same.

Pumping station at Front and Lombard streets	$69,880.00	
Pumping machinery	90,000.00	
Boilers	6,400.00	
Force main, 48″ cast-iron pipe, 3,630 feet	39,950.00	
High level interceptor	1,029,760.00	
Low level interceptor	413,110.00	
Locust Point interceptor	165,909.00	
York street interceptor	42,598.00	
Outfall sewer, City line to Chesapeake Bay	1,722,560.00	
Outlet pipe in the Bay, 5,000 lineal feet	300,000.00	
Total		$3,880,167.00

b. All works are for one million persons.

Pumping station at Front and Lombard streets	$69,880.00	
Pumping machinery	135,000.00	
Boilers	10,400.00	
Force mains, 48″ cast-iron pipe, 3,630 feet	39,950.00	
High level interceptor	1,029,760.00	
Low level interceptor	413,110.00	
Locust Point interceptor	165,909.00	
York street interceptor	42,598.00	
Outfall sewer, City line to Chesapeake Bay	1,722,560.00	
Two outlet pipes, each 5,000 feet long	600,000.00	
Two outlet pipes, extended to 18 feet of water, 7,500 feet	900,000.00	
Total		$5,129,167.00

2. *Precipitation Project.*

a. All interceptors, pumping station, force main and the outfall sewer are sufficient for the sewage from one million persons; the tanks, buildings and all machinery are for about one-third of the same.

Pumping station at Front and Lombard streets	$69,880.00	
Pumping machinery	90,000.00	
Boilers	6,400.00	
Force main, 48″ cast-iron pipe, 3,630 feet	39,950.00	
High level interceptor	1,029,760.00	
Low level interceptor	413,110.00	
Locust Point interceptor	165,909.00	
York street interceptor	42,598.00	
Outfall sewer, City line to tanks.	383,787.00	
Precipitation tanks	630,510.00	
Building and machinery	90,096.00	
Total		$2,962,000.00

b. All works are for one million persons.

Pumping station at Front and Lombard streets	$69,880.00	
Pumping machinery	135,000.00	
Boilers	10,400.00	
Force main, 48″ cast-iron pipe, 3,630 feet	39,950.00	
High level interceptor	1,029,760.00	
Low level interceptor	413,110.00	
Locust Point interceptor	165,909.00	
York street interceptor	42,598.00	
Outfall sewer, City line to tanks,	383,787.00	
Precipitation tanks	1,682,510.00	
Buildings and machinery	280,096.00	
Outfall sewer, from tanks to Chesapeake Bay	1,250,000.00	
Total		$5,503,000.00

3. *Filtration Project.*

a. All interceptors, the pumping station and force mains are for the sewage of one million persons; the tanks and machinery are for temporary precipitation.

Pumping station and accessories	$262,000.00	
Pumping machinery: three 30,000,000 gallon pumps	135,000.00	
Boilers, two 500 horse-power	16,000.00	
Force mains, pumping station to tanks	816,450.00	
Interceptors, as per *b*	1,410,474.00	
Precipitation tanks	288,992.00	
Buildings and machinery	90,096.00	
Total		$3,019,012.00

b. All interceptors and the pumping station are sufficient for the sewage from one million persons; the filtration fields, discharge mains and pumping machinery are for about one-third of the same.

Land for filtration, 1,884 acres	$94,200.00	
Preparing 1,216 acres	1,262,203.00	
Buildings and utensils for 6 stations	40,000.00	
Force and gravity mains	1,445,770.00	
Tunnel, 8,000 lineal feet	811,360.00	
Pumping station and accessories	262,000.00	
Pumping machinery	383,000.00	
Boilers	32,000.00	
Eastern low level interceptor	570,078.00	
Western low level interceptor	129,834.00	
Locust Point interceptor	165,909.00	
York street interceptor	42,598.00	
Eastern high level interceptor	299,490.00	
Western high level interceptor	202,565.00	
Total		$5,741,007.00

c. All works are for one million persons.

Land for filtration, 5,384 acres	$269,200.00
Preparing 3,766 acres	3,416,773.00
Buildings and utensils for 18 stations	120,000.00
Force and gravity mains	4,614,984.00
Tunnel, 8,000 lineal feet	811,360.00
Tunnel, 3,400 lineal feet	429,012.00
Pumping station and accessories	262,000.00
Carried forward	$9,923,329.00

Brought forward	$9,923,329.00	
Pumping machinery	758,000.00	
Boilers	80,000.00	
Eastern low level interceptor	570,078.00	
Western low level interceptor	129,834.00	
Locust Point interceptor	165,909.00	
York street interceptor	42,598.00	
Eastern high level interceptor	299,490.00	
Western high level interceptor	202,565.00	
Total		$12,171,803.00

B.—SUMMARIES FOR ANNUAL MAINTENANCE, INTEREST AND RENEWALS.

1. *Dilution Project.*

a. For immediate needs.

Interest on first cost, $3,880,167.00 @ 4%		$155,206.68
Depreciation and renewals:		
On whole cost, $3,880,167.00 @ 1%	$38,801.67	
On force main, $39,950.00 @ 1% additional	399.50	
On pumping machinery, $90,000 @ 2% additional	1,800.00	
On boilers, $6,400.00 @ 4% additional	256.00	
On siphons, $101,919.00 @ 1% additional	1,019.19	
		42,276.36

Cost of pumping:

Per day:

Chief engineer	$3.00	
Assistant engineer	2.50	
Firemen, 2 @ $1.75	3.50	
Helpers, 2 @ $1.50	3.00	
		$12.00
Oil and waste		1.20
Coal, 3.5 net tons, @ $3.00		10.50
		$23.70
10%		2.37
		$26.07

Carried forward $197,483.04

Brought forward	$197,483.04
365 days @ $26.07	9,515.55
Maintenance of interceptors, 4 men @ $625.00	2,500.00
Maintenance of outfall, 4 men @ 625.00	2,500.00
Dredging at outfall, 1,000 cu. yds., .20	200.00
Superintendent	1,500.00
Total	$213,698.59

b. For one million persons.

Interest on first cost, $5,129,167.00 @ 4%				$205,166.68
Depreciation and renewals:				
On whole cost, $5,129,167.00 @ 1%			$51,291.67	
On force main, $39,950.00 @ 1% additional			399.50	
On pumping machinery, $135,000.00 @ 2% additional			2,700.00	
On boilers, $10,400.00 @ 4% additional			416.00	
On siphons, $101,919.00 @ 1%			1,019.19	
				$55,826.36
Cost of pumping:				
Per day:				
Chief engineer	$3.00			
Assistants, 3 @ $2.50	7.50			
Firemen, 4 @ $1.75	7.00			
Helpers, 3 @ $1.50	4.50			
		$22.00		
Oil and waste		2.20		
Coal, 10.5 net tons, @ $3.00		31.50		
		$55.70		
10%		5.57		
		$61.27		
365 days @ $61.27				22,363.55
Maintenance of interceptors				2,500.00
Maintenance of outfall				2,500.00
Dredging at outfall, 3,000 cu. yds. @ 20 cts.				600.00
Superintendent				1,500.00
Total				$290,456.59

2. *Precipitation Project.*

a. For immediate needs.

Interest on first cost, $2,962,000.00 @ 4%		$118,480.00
Depreciation and renewals:		
On whole cost, $2,962,000.00 @ 1%	$29,620.00	
On force main, $39,950.00 @ 1% additional	399.50	
On pumping machinery, $90,000.00 @ 2% additional	1,800.00	
On boilers, $6,400.00 @ 4% additional	256.00	
On siphons, $14,994.00 @ 1% additional	149.94	
On disposal works, $720,606.00 @ 5-10 of 1% additional	3,603.03	
		35,828.47
Cost of pumping, same as dilution project		9,515.55
Maintenance of interceptors, 4 men @ $625.00		2,500.00
Maintenance of disposal works; provide for 333,000 people @ 35 cts.		116,550.00
Superintendent		1,500.00
Total		$284,374.02

b. For one million persons.

Interest on first cost, $5,503,000.00 @ 4%		$220,120.00
Depreciations and renewals:		
On whole cost, $5,503,000.00 @ 1%	$55,030.00	
On force main, $39,950.00 @ 1% additional	399.50	
On pumping machinery, $135,000.00 @ 2% additional	2,700.00	
On boilers, $10,400.00 @ 4% additional	416.00	
On siphons, $14,994.00 @ 1% additional	149.94	
On disposal works, $1,962,606.00, ½ of 1% additional	9,813.03	
		68,508.47
Cost of pumping, same as dilution project		22,363.55
Maintenance of interceptors		2,500.00
Maintenance of disposal works, provide for 1,000,000 persons @ 35 cts.		350,000.00
Superintendent		1,500.00
Total		$664,992.02

3. *Filtration Project.*

a. For immediate needs, with temporary precipitation.

Interest on first cost, $3,019,012.00 @ 4%		$120,760.48
Depreciation and renewals:		
On whole cost, $3,019,012.00 @ 1%	$30,190.12	
On discharge mains, $816,450.00 @ 1% additional	8,164.50	
On pumping machinery, $135,000.00 @ 2% additional	2,700.00	
On boilers, $16,000.00 @ 4% additional	640.00	
On siphons, $139,803.00 @ 1% additional	1,398.03	
On disposal works, $379,088.00 @ 5-10 of 1% additional	1,895.44	
		44,988.09
		$165,748.57

Cost of pumping:

Per day:

Chief engineer	$3.00	
Assistants, 3 @ $2.50	7.50	
Firemen, 4 @ $1.75	7.00	
Helpers, 2 @ $1.50	3.00	
		$20.50
Oil and waste		2.00
Coal, 5 net tons, @ $3.00		15.00
		$37.50
10%		3.75
		$41.25

365 days @ $41.25	15,056.25
Maintenance of interceptors	2,500.00
Maintenance of disposal works, providing for 333,000 people, @ 35 cts.	116,550.00
Superintendent	1,500.00
Total	$301,354.82

b. For immediate needs, with filtration at Glen Burnie.

Interest on first cost, $5,741,007.00 @ 4%		$229,640.28
Depreciation and renewals:		
On whole cost, $5,741,007.00 @ 1%	$57,410.07	
Carried forward	$57,410.07	$229,640.28

Brought forward			$57,410.07	$229,640.28
On discharge mains and tunnel, $2,257,130.00 @ 1% additional			22,571.30	
On pumping machinery, $383,000.00 @ 2% additional			7,660.00	
On boilers, $32,000.00 @ 4% additional			1,280.00	
On siphons, $139,803.00 @ 1% additional			1,398.03	
				90,319.40
Cost of pumping:				
Per day:				
Chief engineer	$3.00			
Assistants, 3 @ $2.50	7.50			
Firemen, 4 @ $1.75	7.00			
Helpers, 2 @ $1.50	3.00			
		$20.50		
Oil and waste		2.00		
Coal, 17 net tons @ $3.00		51.00		
		$73.50		
10%		7.35		
		$80.85		
365 days @ $80.85				29,510.25
Maintenance of interceptors				2,500.00
Maintenance of filtration fields and discharge mains				53,250.00
Superintendent				1,500.00
Deductions:				$406,719.93
Sale of crops is assumed to offset taxes and to repay:				
Interest on cost of filtration fields, $94,200.00 @ 4%			$3,768.00	
Insurance on buildings and tools, $40,000.00 @ ½ of 1%			200.00	
				3,968.00
Total				$402,751.93

c. For one million persons.

Interest on first cost, $12,171,803.00 @ 4%		$486,872.12
Depreciation and renewals:		
On whole cost, $12,171,803.00 @ 1%	$121,718.03	
Carried forward	$121,718.03	$486,872.12

Brought forward			$121,718.03	$486,872.12
Discharge mains and tunnels, $5,855,356.00 @ 1% additional			58,553.56	
On pumping machinery, $758,000.00 @ 2% additional			15,160.00	
On boilers, $80,000.00 @ 4% additional			3,200.00	
Siphons, $139,803.00 @ 1% additional			1,398.03	
				200,029.62
Cost of pumping:				
Per day:				
Chief engineer	$ 3.00			
Assistants, 7 @ $2.50	17.50			
Firemen, 10 @ $1.75	17.50			
Helpers, 4 @ $1.50	6.00			
		$ 44.00		
Oil and waste		4.00		
Coal, 58 net tons, @ $3.00		174.00		
		$222.00		
10%		22.00		
		$244.00		
365 days @ $244.00				89,060.00
Maintenance of interceptors				2,500.00
Maintenance of filtration fields and discharge mains,				
300 men @ $470.00			$141,000.00	
3 men @ 650.00			1,950.00	
				142,950.00
Superintendents, 2 @ $1,500.00				3,000.00
				$924,411.74
Deductions:				
Sale of crops is assumed to offset taxes and to repay:				
Interest on cost of filtration fields, $269,200.00 at 4%			$10,768.00	
Insurance on buildings and tools, $120,000.00 @ ½ of 1%			600.00	
				11,368.00
Total				$913,043.74

Z

APPENDIX V.

LIST OF PLANS ACCOMPANYING REPORT.

Plate A: Map showing Sewerage Districts, Intercepting Sewers, and Main District Sewers, for Dilution Project.
Plate B: Map showing location of Main Outfall Sewer; also location of Precipitation Tanks.
Plate C: Profiles and Sections of Outfall Sewer, also Plan, Profile and Section of Siphon under Bear Creek.
Plate D: Plan of Settling Basin, Gate House and Outfall.
Plate E: Plan of Precipitation Tanks.
Plate F: Plan of Pumping Station for Dilution Project.
Plate G: Map showing Sewerage Districts, Intercepting Sewers, and Main District Sewers, for Filtration Project.
Plate H: Map showing Filtration Fields at Glen Burnie.
Plate I: Plan and Profile of Discharge Mains; also Sections of Tunnel and River Crossing.
Plate J: Sections of Intercepting Sewers and Siphons.
Plate K: Profile of Intercepting Sewers.
Plate L: Plan of Pumping Station for Filtration Project.
Plate M: General Map, showing Outlines of Filtration Project.
Plate N: Rainfall Diagram.
Plate O: Method of Construction of Filtration Beds.

APPENDIX D

REPORT OF GENERAL WM. P. CRAIGHILL

APPENDIX D.

BALTIMORE, *July 20, 1897.*

TO THE SEWERAGE COMMISSION OF THE CITY OF BALTIMORE.

Gentlemen:—In accordance with your invitation of April 17th, I have had under careful consideration certain questions, suggested by you, relative to the disposal of the sewage of Baltimore by its discharge into the waters of Chesapeake Bay.

That some proper and sufficient method of sewage-disposal has long been a matter of urgent need for such a great and growing city as Baltimore will be readily admitted by every thinking man who is acquainted with existing conditions which are becoming more pressing every day. These conditions have been fully discussed by others, and I refrain from saying anything in reference to them.

I have had the opportunity, through your courtesy, of examining the elaborate report made to your Commission by Messrs. Rudolph Hering and Samuel M. Gray under date of November, 1896. Baltimore is fortunate in having had the services of such experts on the treatment of sewage-disposal and in being able to take advantage of the experience gained in past years in many other cities in this country and in Europe in that matter.

Much valuable information is also to be found in the able report of August, 1881, made by one of your own citizens, Mr. Chas. H. Latrobe. His conclusion then was that the "outfall main" or conduit should be carried to the open water of the bay.

Hering and Gray remark that "there are several methods, according to which, sewage can be safely and properly disposed of; namely, by a dilution in large bodies of water, by precipitation and separation from the sewage of a large portion of the organic matter, and by filtration of the sewage through porous soil." The applicability of all these methods, Dilution, Precipitation and Filtration, to the case of the City of Baltimore, is very carefully and fully discussed by these gentlemen, and in comparing they specify them as "the discharge of crude sewage into the deep waters of the

Chesapeake Bay, the discharge of clarified sewage into the Patapsco River and eventually into Chesapeake Bay near the shore, and the purification by filtration in Anne Arundel county." The whole subject is considered from the point of view of existing conditions and what may reasonably be expected when Baltimore will have a population of a million of people.

After presenting in detail the advantages and disadvantages of the three methods, Dilution, Precipitation and Filtration, with estimates of cost, these gentlemen strongly advocate a disposal of the sewage by Filtration in Anne Arundel county at a location where the natural conditions are highly favorable for the application of that method.

The summary of estimates of cost of the three methods given by Hering and Gray is as follows:

Project.	Construction, total cost.	Maintenance, interest and renewals per annum.
1. *Dilution.*		
a. For immediate needs.......	$3,880,167	$213,700
b. For one million persons.....	5,129,167	290,460
2. *Precipitation.*		
a. For immediate needs.......	2,962,000	284,400
b. For one million persons.....	5,503,000	665,000
3. *Filtration.*		
For immediate needs with		
a. Temporary precipitation	3,019,012	301,355
b. Filtration at Glen Burnie...	5,741,007	402,752
c. For one million persons.....	12,171,803	913,044

The experts state that "the final disposal of the sewage required the consideration of three methods, which are all applicable and according to any of which the sewage can be disposed of without offense."

In view of the fact here stated, which may be accepted on such high authority, a question for those who will pay for the sewage-disposal very naturally arises; if the method of Dilution can be used satisfactorily and without offense by Baltimore at a cost less than half that of Filtration, why should not that method be adopted?

The experts say, that "to dispose of sewage by dilution means to discharge it into running water in a suitable proportion so that no putrefaction will take place, and that the oxygen contained in the water will gradually decompose the organic matter of the sewage and convert it into harmless compounds. When sewage is thus diluted it gives no offense." This method has been fully examined by your experts, as appears from the following statements in their report: "In order to show the probable effect of discharging sewage into the Patapsco River at different points under the least favorable conditions, the necessary calculations were made. These conditions occur when the dry weather flow enters the river from its drainage area and therefore contributes the least amount of water to dilute the sewage." And they state further, as follows: "Could the sewage of Baltimore be discharged into the current of the waters of the Chesapeake Bay, it is safe to assume from what was said above that, at the lowest figure applied to non-tidal streams, the sewage of about two and a quarter million people might thus be disposed of at the most unfavorable time." They say also, "a disposal of the sewage of Baltimore by dilution therefore would mean nothing less than the building of a sewer to near North Point and of discharging its contents into the current of the Chesapeake Bay. No point nearer the city, and no smaller body of water, such as Back River, would prevent dissatisfaction." In their comparison of the several methods of sewage-disposal, Hering and Gray say: "When we consider that a discharge of crude sewage into Chesapeake Bay does not at once effectually dispose of it, but allows it to oscillate with the tides in the navigable waters and over oyster beds before it is thoroughly dispersed * * *"

In view of the objections just given to the disposal of the sewage through an outfall near North Point, it seemed expedient to your Commission to give further and very careful consideration to them before submitting a recommendation to the Mayor and City Council of the city. Accordingly it was decided to make additional observations of the direction of the currents at all stages of the tide in the vicinity of the point indicated by Hering and Gray for the mouth of the outfall sewer.

Fortunately for the object in view a re-survey of the Chesapeake Bay was about to be undertaken under the supervision of the Superintendent of the U. S. Coast and Geodetic Survey, a part of the work consisting of observations of the directions and velocities of the currents near North Point and elsewhere in the adjacent parts of the Bay. The Superintendent of the Coast Survey very courteously agreed that all results of this special kind which could be useful in the line of investigation of the Sewerage Commission could be at once placed at the disposal of the Commission. Lieut. Tillman, U. S. Navy, the officer in charge, has evinced a great interest in the matter, and his observations and results have been of great value. They were all made from a point about two and a quarter miles northeast of North Point and about one mile from the shore.

A study of the observations by Lieut. Tillman led to the conclusion that, if the outfall were at the point indicated off North Point, there would be danger at certain stages of the tide of a movement of some of the sewage towards Sparrow's Point and the shores near North Point. And here it may be said, that even in that event, the portion of the discharged sewage thus lingering would probably have been long enough in the water of the Bay to be thoroughly diluted and made inoffensive.

It was decided, however, from abundant caution, to consider other points for the outlet, some distance to the east and north of North Point, and a special party was organized to make additional current observations under the immediate direction of Mr. Kennedy, acting under the supervision of Mr. Allen, Principal Assistant Engineer of the Commission. Accordingly, a large number of floats were set adrift at all stages of the tide from points east of the Rear Light of the ship-channel and approximately 0.92, 1.42, 1.92, 2.42, 2.92, and 3.42 miles from the same.

There was a tendency also in some of the Kennedy floats to drift at times towards and hang around the western shore near and north of North Point, when the floats started from points less than two miles from the shore, as there is a manifest eddy which sweeps them in that direction on the flood tide, but this tendency is less as the point of setting the float loose is farther from the shore; moreover, as remarked before, during the observed intervals elapsing after the times of starting such floats and their approach to the shore, there would be ample opportunity for the dilution of any sewage taking the same course by admixture with the large volume of water with which it would be in contact in its movements from the outlet. The conditions at and near the mouth of the Patapsco River are far different from those under the eyes of the citizens of Baltimore in the Basin in the city, and at Spring Garden, where one of the largest sewers empties. There is no fresh water entering the upper part of the Basin except what flows from the surface of the streets during rains, and that is much polluted by what it gathers on its way. Spring Garden is not in a much better condition. At the mouth of the Patapsco there is not only the vertical oscillation due to the rise and fall of the tides, but there is the constant horizontal movement due to the currents generated by the tides and the great outpour of fresh water from the Susquehanna and other rivers, so that sewage discharged into the Bay two miles from the shore commences to be diluted at once, and becomes more and more so in an increasing ratio the longer it is out of the sewer and the further it goes from its mouth, until finally, after passing the mouth of the Patapsco in its movement down the Bay, or even sooner, its offensiveness will have entirely disappeared.

If sewage were discharged only during ebb tide, the tendency to hang around the mouth of the Patapsco would be much less, and it might for that reason be found expedient to arrange basins on shore to receive and hold the sewage during the period of flood tide and discharge it only upon the ebb, but I do not believe that will be ever necessary. A favorable circumstance in this connection is found in the fact that about one-half of the sewage of a city is discharged in eight hours, whereas the ebb tide is flowing out at least twelve of the twenty-four.

It is understood that your Commission proposes to discuss the possible effect upon the oyster beds in the portion of the Bay where sewage might be found in the event of the adoption of the Dilution plan. I may, however, remark that in my opinion that question is not a serious one, as few, if any, valuable beds of oysters would be injured by the diluted sewage under any circumstances, and there would be no great hardship even if, to a moderate extent, there should be such an injury, inasmuch as in any case of a work of vast benefit and importance to a great community, like the population of one of the largest cities of our country, there is always more or less injury caused to individuals or to a small part of that community. It would be easy for the City of Baltimore to secure for itself from the Legislature of the State complete control of any beds of oysters at all endangered by its sewage and thus prevent their use.

One of the most formidable objections in many cases to the dilution method of disposing of sewage is the danger to other communities at lower points of the stream or other body of water used for the purpose. This objection does not exist in the case under consideration. There is no large, or even a small, community to be disagreeably affected by the plan now proposed, nor is such a community likely ever to appear within a long distance from the point recommended for the outfall.

The small volume of available water is also a great objection to the use of the dilution method in many localities. This objection does not exist in the present case. The Bay is seven miles wide where the sewage is proposed to be emptied into it. The depth varies from three feet at the Rear Channel Light to 25 or 30 feet not far from the proposed outfall. The great river Susquehanna is constantly pouring an immense volume of fresh water into the Bay near Havre de Grace, all of which must flow past the line on which the outfall of the sewage of Baltimore is proposed to be located. At a low stage of the river, though not the lowest, there is a discharge above Port Deposit of 35,000 cubic feet a second, which in 24 hours would amount to more than 3,000 millions of cubic feet. There are only about 20,000,000 cubic feet of sewage in 24 hours to be treated. With a rise of three feet above low water the discharge at the same place was 100,000 cubic feet per second, which would give 9,000 millions of cubic feet in 24 hours. A freshet of 17 feet at Port Deposit would give a discharge of 900,000 cubic feet a second, which would be 75,000 millions of cubic feet in 24 hours. This last, however, would be a rare and exceptional case.

The figures above given are derived from a U. S. survey of 1894 and 1895, at a point near Port Deposit and just above tidal influence. They are somewhat larger than those used by Hering and Gray, derived from points higher up the river, but their figures are quite large enough for all the needs of the present case, and it is always best in discussions like this to view the situation from the most unfavorable standpoint.

A high freshet in the Susquehanna, one of the greatest rivers on the Atlantic coast, is an annual occurrence and would produce an enormous cleansing effect on the portion of the Bay off the mouth of the Patapsco, should any such cleansing be needed. The same can be said of the effect of the scouring caused by the large masses of ice which pass out of the Susquehanna every winter.

But there is no good reason to expect any such need to arise when it is remembered that the sewage which would flow into the Bay would be freed of all bodies which could not pass through a hole an inch on a side, as it is proposed to have screens to catch all such matter which would be taken out and burned. All matter capable of solution would be comminuted before reaching the point of outflow. Thus, what would reach Chesapeake Bay would be little more than polluted water, not very offensive in any way, even to the nostrils of persons near at hand. This is the actual experience near Boston and other places where the dilution method properly arranged is applied with success.

To the outflow from the Susquehanna above Port Deposit is also to be added, as available for the dilution of the sewage from Baltimore, the water from Principio, Northeast, Elk and Sassafras Rivers from the eastern shore north of the Patapsco, and from the Bush, Gunpowder and Back Rivers on the west shore. The water from the watersheds of the Patapsco and its tributaries should also be added to the volume available for the dilution of the sewage of Baltimore, as both must pass together down the Bay below the mouth of the Patapsco.

It is well here to call attention to the following extract from the River and Harbor Act of August 17th, 1894, which is very stringent in its prohibitions. Section 6. "That it shall not be lawful to place, discharge, or deposit, by any process or in any manner, ballast, refuse, dirt, ashes, cinders, mud, sand, dredgings, sludge, acid, or any other matter of any kind other than that flowing from streets, sewers, and passing therefrom in a liquid state, in the waters of any harbor or river of the United States, for the improvement of which money has been appropriated by Congress, elsewhere than within the limits defined and permitted by the Secretary of War; any and every such act is made a misdemeanor, and every person knowingly engaged in or who shall knowingly aid, abet, authorize, or instigate a violation of this Section shall, upon conviction, be punishable by fine or imprisonment, or both; such fine to be not less than two hundred and fifty dollars, nor more than twenty-five hundred dollars, and the imprisonment to be not less than thirty days nor more than one year, either or both united, as the judge before whom conviction is obtained shall decide, one-half of said fine to be paid to the person or persons giving information which shall lead to the conviction of this misdemeanor." It will be observed that just such matter as is to be treated by the dilution method of disposing of the sewage of Baltimore is excepted from the operation of this law.

Some thirty years ago a thorough study was made of the currents in the Bay north and south of the mouth of the Patapsco River when the subject of the new location of the ship-channel was under consideration. Experience has demonstrated that the conclusions then drawn were sound and correct. Conditions have not materially changed so far as the currents are concerned. These currents are due to three causes: the outflow of fresh water from the Susquehanna and Patapsco and their tributaries and other streams emptying into the Bay south of Havre de Grace, the tides and the winds. The influence of the tides on these currents is much less in the upper part of Chesapeake Bay than in many other localities where the vertical movement is very much greater. The influence of the wind is not great, except in storms which are exceptional and never of long duration.

A point of the first importance is the fact beyond question that, however the winds may blow and the tide may rise and fall, the great flow of fresh water from the Susquehanna, Patapsco and other streams never ceases and is always in the main downward and outward until it is lost in the ocean. And this downward movement is reinforced by the ebb tide during at least 12 of every 24 hours. The force which may be depended upon for the removal of the sewage of Baltimore, if poured into the Bay at a properly selected point, is therefore far greater than that which would tend to hold the sewage or push it up-stream for a short time under certain conditions of tide and wind. This is the force which was relied upon for the maintenance of the increased depth to be given in the new ship-channel, and the confidence in it to accomplish the desired result, which was at first a theory based upon study and observation, has been justified by actual results. Existing facts speak for themselves.

The volume of the flow of the Susquehanna and its tributaries far exceeds that of the Patapsco. The resultant of these two forces when they meet near the mouth of the Patapsco is necessarily near the western shore, where the present channel was successfully located. The effect of this greater force of the Susquehanna flow, impinging upon the flow from the Patapsco, is to check the latter to a certain extent, and an eddy is formed, especially during the flood tide and when the wind is in certain directions, and thus a movement is caused like a reflex current which sweeps in a northeasterly direction along the western shore north of North Point until it is drawn again into the great down current of the Susquehanna farther eastward.

The observations of Lieut. Tillman near North Point and those of Mr. Kennedy farther northward and eastward, have emphasized the fact stated above in a most pointed way, and the diagrams of the movements of the floats made in your office by Mr. Allen, or under his supervision, show this reflex movement very graphically. They also show that if the point of discharge of the sewage be located sufficiently far from the western shore, not less than two miles, and sufficiently far north of North Point, it will be carried out into the main current from the Susquehanna and then southerly. There may be a little northerly movement in the southern course, but the general progress is southerly or toward the ocean.

While the conclusions from the observations of floats this year are interesting and in conformity to known conditions as to directions and velocities of currents, your Commission is aware that owing to bad weather and other untoward circumstances, they were not so extensive and complete as is desirable before a final location for the mouth of the outfall sewer.

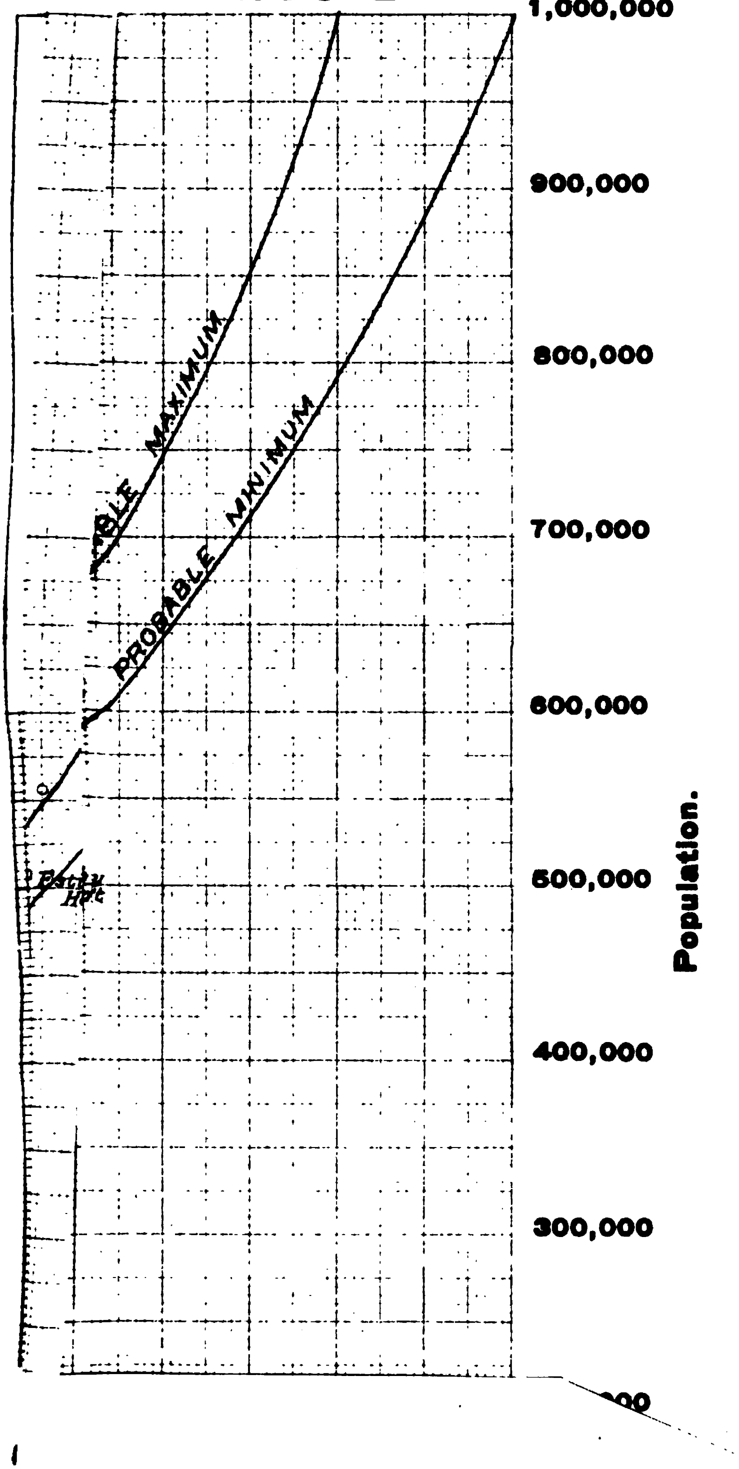
It is right to call attention here to the fact that the amount of the total daily sewage of Baltimore which is put on a very liberal estimate at 20,000,000 of cubic feet is only 1-150 of the ordinary daily low-stage outflow of the Susquehanna alone; there is thus an ample supply of water for all purposes of dilution and oxidation of the sewage.

In conclusion I have therefore to state that after a long observation and study of the currents of the Bay above and below the mouth of the Patapsco, and full and careful consideration of all the conditions and circumstances of the present case, it is my decided conviction that the dilution method of disposing of the sewage of Baltimore *may be* adopted with entire safety and without offense, provided the outlet of the sewer into the Bay be not farther south than a line eastward of the rear range of the ship-channel and not nearer the western shore than two miles; and the dilution method *should be* adopted as being far more economical, both in first cost and in maintenance, than the method of filtration. To determine precisely the best point for the outlet of the sewer into the Bay there should be additional observations made in connection with the detailed surveys, which should precede the definitive location of the system before placing the work under contract.

Very respectfully yours,

WM. P. CRAIGHILL.

Plate I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